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QUEER FISH

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QUEER FISH

ESSAYS ON MARINE SCIENCE AND OTHER ASPECTS OF BIOLOGY

By
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PREFACE

INTEREST in Biology is rapidly increasing. The thinking man is realizing that the biologist is not a harmless eccentric but one who is making an important contribution to human knowledge the fruits of which will be an increase in the material prosperity, and possibly the general happiness, of the human race.

The short articles which make up this volume deal with various aspects of modern biology in a manner which, it is hoped, will interest the general reader. Particular stress is laid on that branch of biology in which the author is particularly interested, namely marine biology and the science of oceanography. Too little attention has hitherto been paid in popular scientific writing to this side of biology. This, though it might easily be pardoned were Britain an inland country, is far from excusable when she is instead the leading maritime nation in the world. It is the earnest hope of the author that this small book may assist in however

small a way towards the remedying of the prevailing ignorance of a branch of science which is not only fascinating in itself, but aims at an eventual farming of the products of the sea and their intensive exploitation for the benefit of mankind.

The great majority of the articles have already appeared in print, number 1 in "The Review of Reviews", 2, 3, 4, 5, 6, 8, 9, 17 and 20 in "The New Statesman", 7, 13, 16 and 18 in "Discovery" or "Conquest" which was recently incorporated in it, 14 in "T. P.'s Weekly", 15, 21 and 23 in "The Nation and Athenaeum", and 19 in "The Outlook". Number 12 represents a combination of two articles which appeared one in "Discovery" and the other in "The New Statesman". The author begs to acknowledge his indebtedness to the Editors of these journals for permission to republish in volume form these contributions to their columns.

QUEER FISH

I. Marine Biology

Fisheries

1. *The Great Fisheries*

The extensive coastline of the British Isles and their position on the edge of the Continent of Europe surrounded by the shallow water which covers the continental slope, and which teems with many kinds of edible fish, have resulted in the British fisheries becoming the largest in the world. In 1925 nineteen and three-quarter million hundredweights of fish were landed, which represented a value of nearly twenty million pounds; about 60,000 men and boys were regularly employed in the fisheries that year, besides some 7,000 who were occasionally employed. The richness of her fisheries has proved in the past one of the most valuable of the natural resources of Great Britain, while in the future there is reason to hope that improved methods of fishing, of marketing and preserving the catch and a better knowledge of the

natural history and habits of the fish, may result in a further increase in their value.

Fish can be divided into two great groups; the boney fish, such as the cod or herring, and the cartilaginous fish like the dogfish and skate. The boney fish are by far the most numerous and the most important, and the majority of those which are caught for food belong to three large families. First there are the members of the cod family, of which the cod, haddock, hake, whiting and ling are the most important. These fish live and feed mainly on the sea bottom, but they are not all found in the same parts, the cod and haddock are northern fish which are caught chiefly in the North and Norwegian Seas, while the hake, on the other hand, is a southern fish in pursuit of which British trawlers steam across the Bay of Biscay and southwards along the coasts of Morocco.

The herring family forms the second important group of edible boney fishes. Amongst these the herring stands out pre-eminent both on account of its great abundance and high food value. The herring has not been without its influence on the course of history, and both the Hanseatic League and the later Dutch Republic owed much of their greatness

to their exploitation of the herring fisheries. The great shoals of herring which appear in various regions around our coasts each year are pursued by a special fishing fleet, and the product of their catches, some four million hundredweights, formed one-fifth of the total weight of fish landed in 1925. Related to the herring are the sprat, which is now being fished in increasing numbers for subsequent canning, the anchovy, and the pilchard. The last-named is a southern fish caught in large numbers off the Cornish coast. All the members of the herring family, unlike the cod and its relatives, live in mid-water or near the surface of the sea; the mackerel is also found there, and very different methods of fishing from those employed for the bottom-living fish are required in these fisheries.

The last important group of bony fishes comprises the flatfish. Unlike the fish already considered, which have all rounded, torpedo-shaped bodies, the flatfish, though they begin life with symmetrical bodies, early experience a strange "metamorphosis" when their bodies become flattened, their heads distorted and the eye from one side migrates to the other, so that the animal is able always to lie on

one side with both eyes facing upwards. All of these fish live on the sea bottom. The largest of our flatfish is the halibut, which is caught in the North Sea; turbot and brill are less common and are caught in the English Channel as well as in the North Sea; plaice are the most numerous and important of the flatfish and are found all round the coast; soles are shallow-water fish and live in more southern waters, they are not abundant and are a luxury fish; flounders and dabs are often common in the shallow waters of estuaries but are usually only eaten locally.

It is only of recent years that the public have begun to appreciate the food value of skates and dogfish, and consequently this fishery has advanced rapidly in value. Although closely related and both widely distributed, these fish are very different in their mode of life, the dogfish—really small sharks—being active fish which range through all depths of the sea and pursue the herring shoals, while the skates are sluggish and lie on the bottom where they find their food. Their bodies are flattened, not, like the flat-fish, from side to side, but from above to below.

These are the chief food fishes caught in British waters; there are many others, but

in an article of this length it is impossible to deal with any but the most important.

The methods of fishing naturally depend on the habits of the fish that are to be caught. Thus, very different methods are needed for catching bottom-living animals like flatfish than for herrings and pilchards, which swim about in great shoals in mid-water, coming up nearer the surface at night. The chief methods employed are the trawl, line, drift-net and seine-net, all of which are modified in various ways for catching particular fish. The two first are used for catching bottom-living fish and the others for surface fish.

The trawl is by far the most important instrument used in fishing. The older fishing smacks, which are driven by sails though they often carry an auxiliary motor, use what is known as a beam-trawl. This trawl consists of a triangular bag open at both ends and anything up to 80 feet long. The wide end is held open by the wooden beam which gives the trawl its name and which may be 50 feet long, and at either end of this are stirrup-shaped "irons" which serve to keep the beam clear of the bottom. A "head-line" is fastened to the beam and irons, while beneath and connecting the lower

end of the irons is a "foot-rope" usually of stout 3-inch rope which is more than half as long again as the head-line and is often weighted with iron chains. The net is made of well-tarred hemp twine with a wide mesh near the mouth but much smaller near the narrow or "cod" end, and is fastened to the head-line and foot-rope. There are two backwardly directed folds of netting about half-way along the net which are known as "pockets" and form a trap into which it is easy for the fish to enter, but out of which it is difficult for them to escape.

A thick rope called a "bridle" is fastened to each of the irons and these meet to be secured to the powerful trawl warp, which usually consists of about 150 fathoms of 6-inch rope. Before the trawl is let down, or "shot", the cod-end is laced up, the ship then sails full speed ahead while the required length of rope is paid out, and finally the trawl is dragged along the sea bottom at a speed of about two knots in the form of a great, wide-mouthed bag, into which are swept all animals which lie in its path. The wear upon the foot-rope and the under side or belly of the trawl which drag along the

bottom is naturally very great, and these have to be renewed frequently during the fishing season. After an appropriate period the trawl is raised, usually by means of a mechanically-driven winch. As soon as the beam appears on the surface the two ends are made fast and the whole hoisted up, the net is gathered in, the cod-end unlaced and the mass of animals, weed and stones which have been collected allowed to fall out on the deck. The sailing smacks which use this type of trawl do not usually venture far afield and work best in depths of 30 fathoms or less.

As a result of the introduction of steam, not only have the picturesque fishing smacks with their red or brown sails been replaced by the ugly but highly efficient steam trawlers, vessels up to 120 feet long which carry coal for long voyages and stocks of ice for keeping the fish which may be caught as far distant as the coasts of Morocco or in the White Sea, but the older beam trawl has made way for the larger and more efficient "otter-trawl". This trawl is a modification of the beam-trawl, but instead of the beam the mouth of the trawl is kept open by two "otter boards". These are heavy wooden

frames like house doors, but shod with iron, which are fastened one at each side of the mouth at the junction of the head-line and foot-rope, which are secured to them. A separate steel-warp is fastened to each of them and in such a manner that, owing to the pressure of the water, the two boards fly apart as the trawl is towed through the water. In this way the mouth of the trawl is kept open without the use of a cumbersome beam, while the trawl can be made much larger. In the largest trawls of this type the head-line may be a hundred feet long, twice that of the largest beam-trawl.

The largest steam trawlers carry two of these trawls, one of which is in use while the other is being prepared so that it can be shot as soon as the first one is hauled in. This is accomplished by winding the steel warps round great, steam-driven winches. The steam trawlers are able to work at far greater depths than the smacks, up to 200 fathoms in the case of the hake fishery off Morocco, and are also able to cover far more ground, on account of the greater size of the trawl and of their greater and more constant speed.

As we have seen, the trawl is essentially an apparatus for catching fish on the sea

bottom ; it can, however, be shot in the midst of a shoal of herring in mid-water, and these can be caught in great numbers. A special type of otter-trawl with a third board arranged horizontally above the trawl has been devised for this type of fishing and is largely used by French fishing vessels. Under normal conditions the trawl is always swept along the bottom of the sea and the catch is very varied, great numbers of the lower invertebrate animals being caught as well as fish. Of the latter, the haddock is the principal representative caught in the North Sea, although cod and plaice are also of great importance, while great numbers of such fish as whiting, skates, lemon soles, dabs, gurnards and many others are caught in this area. Many trawlers steam beyond the North Sea into the Norwegian Sea, towards Iceland and farther, and their chief catch is cod together with many haddock and plaice. Trawlers from the western fishing ports do most of their fishing on the grounds off the south and west of Ireland and off the west of Scotland ; in the deeper water of the southern area hake is the principal catch. The fishing smacks confine their attention to the shallower water in the North Sea, English

Channel, and Irish Sea, where they catch whiting, many of the flatfish, such as plaice and dabs, and also skates and rays, to mention only the most important. Besides the commoner fish, both smacks and trawlers land large quantities of the more valuable "prime" fish—soles, turbot and brill—although these have no longer the pre-eminent position amongst food fishes that they once enjoyed.

Lining is the other principal method of catching bottom-living fish. This is carried on in small vessels all around the coast, but there are also large modern steamships engaged in this type of fishing. Long lines to which, at about six foot intervals, are attached short lengths of rope bearing hooks are used. The hooks are baited ashore and the lines then carefully coiled in tubs to be later thrown overboard on the fishing grounds, each line being attached to the one which has preceded it until a length of anything up to 7,000 yards of line is put out. The line is then buoyed and secured and left, usually for a day, before it is hauled in and the fish removed from the hooks. The catch consists chiefly of halibut—especially off the north of Scotland—ling, haddock and skates.

Obviously to catch the mid-water or

"pelagic"—as opposed to the bottom-living or "demersal"—fish, such as the herring, pilchard, sprat or mackerel, very different methods must be employed. The herring fishery is the most important branch of this type of fishing. The herrings are caught when they assemble in huge shoals for the purpose of spawning, and these shoals appear at different times of the year in the shallower water off many regions of the coast ranging from Stornaway in the north to the English Channel in the south. In almost every part of the year, therefore, the herrings are to be caught somewhere, and wherever they appear they are fished relentlessly by the herring fleet, which consists of local ships reinforced by vessels from the fishing ports of the east of England and Scotland. The usual method of catching herrings is by drift nets, hence the ships are called drifters and not trawlers. The modern drifters are steam driven, but are smaller than the steam trawlers as they do not need to travel such great distances. The drift-nets are perfectly simple, consisting of long nets about eight yards wide which are fastened end to end as they are paid out until they may extend for anything up to two miles. They are buoyed at one side

and weighted at the other so that they float out behind the ship as a vertical wall of netting. By appropriate weighting the nets can be sunk to the level at which the shoals are swimming. Fishing is done at night when the fish come near the surface. The nets are not fastened, but drift with the tide and, unlike the trawl, it is not the net which is the active agency, but the fish, for, in their endeavours to force their way through the netting, they are caught by their gills in the meshes and strangled. The mesh of the net depends, naturally, on the size of the fish to be caught, and different meshed nets are used for herring, mackerel, pilchard and sprat. The only other fish usually caught in the nets are dogfish, which pursue the herrings and often get tangled up in the nets, to which they frequently do great damage.

In certain parts herrings are caught in seine-nets, which are not unlike drift nets, but which are shot round the shoals, two or three small boats being needed for the process. After the circle has been completed the net with the enclosed fish is carefully hauled in. This method of fishing is largely used in the Cornish pilchard fishery either out at sea or, when the shoals are near the

land, from the shore. Only one boat is needed under the latter conditions, one end of the net being held ashore while the seine is being paid out round the shoal from a rowing boat. The nets used are usually about 100 fathoms long and are deepest in the middle, tapering to narrower wings at either end. When used at sea a second and smaller "tucking-seine" is used and drawn under the main seine with its enclosed fish, which are then raised to the surface and collected in baskets. Unlike the trawl, which crushes the fish, and the drift-net, which strangles them, the seine catches them alive. Great hauls of pilchards have been made in this manner on the Cornish coast, as many as 600,000 fish having been the estimated haul in one seine! The use of the seine goes back to the days of the ancient Greeks and, unlike other methods of fishing, has been quite unaffected by the introduction of steam.

The life of a fisherman is precarious. There is the constant danger of storms and shipwreck which annually exact a heavy toll of men and ships; in 1924 seventy fishing vessels were totally lost and seventy-six badly damaged while 102 fishermen lost their lives.

There is also uncertainty about the catch, for the fisheries fluctuate from year to year. The causes of this are still incompletely known, although, as the result of marine biological research, they are in many cases being gradually discovered.

Fish, even the sluggish, undertake periodic migrations, and the extent and direction of these must be known in order that the fish can be caught when most numerous and most accessible. The reasons for these migrations are various. They may be due to the physical conditions of the water, especially temperature, salinity and the nature of the currents. Thus the cod, which lives always in cold water and is the principal fish caught off Norway, only comes into the North Sea in numbers in the winter. The flow of water from the Norwegian Sea into the Baltic conditions the migrations of fish into the Kattegat and Baltic. The herring especially is influenced by fluctuations in the ocean currents possibly because it depends for food upon the microscopic life which the sea contains and this varies in quantity according to the nature of the water.

An important cause of fish migration lies in the need for finding suitable conditions for

spawning, and these may be far distant from the feeding grounds. The most striking instance of this type of migration is furnished by the freshwater eel which, after growing and maturing in the rivers of western Europe, finally feels the need for spawning. Every autumn great shoals of these "silver" eels collect in the rivers and swim down into the sea and then 3,000 miles across the Atlantic into the Gulf of Mexico, where they descend into the deep water and spawn, afterwards dying. The young fish which develop from the spawn make their way slowly towards Europe, growing as they go, and, after three years, appear as tiny "elvers" about the estuaries of our rivers, up which they swim to find food and protection till their turn comes for spawning. The herring is an example of a fish which feeds in the open sea some distance from the land, but migrates to shallower water to spawn.

The need for food is another compelling cause of fish migrations. It is the mid-water and not the bottom fish which show this type of migration best. Both mackerel and herring spend the greater part of their lives in pursuit of the microscopic life which forms their food.

These periodic influxes of vast numbers of fish make imperative some system of preserving fish unless there is to be great waste during the period of plenty to be followed by a dearth of fish later. This is particularly the case with the herring fishery, where great numbers of fish are often taken in a single night. The surplus fish are cured by salting or smoking, and at one time much of this fish was exported to Germany, Russia, and the Baltic ports; since the war there has been a great diminution in this trade, German dealers now preferring to buy the fresh or "green" fish rather than pickled fish. In the same way Cornish pilchards are salted and preserved, the majority being exported for sale to Italians, either in their own country or in the United States. In the Scottish fishing ports the curing of haddock provides an important industry. Of recent years there has been much scientific investigation with a view to establishing curing and canning industries at all our leading fishing ports; this work cannot be too highly commended, for the importance of minimising the waste of fish, both from the standpoint of the nation's food supply and of the livelihood of the fishermen must be clear to all.

Finally, attention must be drawn to the very unsatisfactory conditions which are gradually destroying the privately owned fishing smacks. These were once the mainstay of our fishing fleet, and their personnel still represent the finest of the fishing population. These men sell their catch immediately on landing, usually to fish dealers who, by combining amongst themselves, can pay practically as little as they please. The dealers stand to lose little or nothing and often realize large profits out of all proportion to the part they play in the distribution of the fish. The fisherman, on the other hand, who is the producer and who risks his all, gets far less than his fair share in the profits of the industry. But the fishermen are far too individualistic to combine amongst themselves, thus providing the best remedy. Failing such combination, drastic legislation would appear to be the only hope of staying the present decline in the number of privately owned vessels. Those who man them have played a great part in the history of this country, and it will be an evil day when the cupidity of a few men shall have driven them from the calling which their ancestors for generations have followed, and deprived them

of that freedom which has made them what they are.

2. *Ocean Currents and the Fisheries*

As our knowledge of the conditions of life in the sea grows greater, the intimate connection between the distribution of fish and physical conditions in the water becomes increasingly apparent. Thus the study of hydrography—the application of physics and chemistry to the investigation of the sea—is becoming more and more an economic necessity, and the naturalist is continually looking to the hydrographer to assist him in explaining the mysterious fluctuations which continually occur in the great fisheries.

The great fisheries of the world are situated in the shallow waters near the edge of continents. To take but two examples, there are the teeming cod banks off Newfoundland and the great European fisheries from the Norwegian Sea to the shores of Morocco. The amazing abundance of cod on the Newfoundland banks is due to the peculiar conditions in the sea, for it is in this region that the cold Labrador current which flows from the Arctic meets the warmer waters

which come from the Gulf of Mexico. The mixing of these waters, besides being responsible for the prevalence of fogs on the banks, provides ideal conditions for the spawning and growth of cod. The colder water, being the heavier, sinks to the bottom, and in this cold water the cod spawns, while the mixing of the waters nearer the surface, by ensuring a continuous supply of the necessary chemical substances, allows the microscopic plant and animal life on which the young cod feed to increase to an unusual extent. A similar mixing of waters along the coasts of Europe is brought about by the upwelling of deep water in the regions near the land, with a similar beneficial effect on the growth of the floating life.

It is not, however, to generalities about the influence of currents on sea fisheries that I wish to draw attention here, but to one individual, and most interesting, example of the effect of a change in the character of the sea water on the abundance of fish in a particular area. Professor Otto Pettersson of Stockholm, a most distinguished hydrographer and one of the founders of the International Council for the Exploration of the Sea, which has just completed a

quarter of a century of most valuable service, has recently published in the Journal of the Council an exceptionally interesting paper on the hydrography, climate and fisheries of the Skagerak, Kattegat and the other seas on the east of Denmark.

This region is of more than usual interest because it is a transition area between the Baltic—which, on account of the great number of rivers which flow into it and the very slight evaporation, is much less salt than the open sea—and the North and Norwegian Seas. There is a continuous current of surplus fresh water passing out of the Baltic, mainly through the Great Belt between Jutland and the Danish Islands, while beneath it there is an under-current of salty oceanic water flowing into the Baltic. This always keeps below the outward current because of the greater density of salt water. On either side of the Kattegat channel, which runs almost due north and south between Jutland and the mainland of Sweden, there is a series of Danish and Swedish light-ships, and from these for the past forty years hydrographical observations have been made daily. The salinity and temperature of the water have been continuously recorded for

the whole of this period and also the direction and speed of the water currents.

From the mass of data thus accumulated, Professor Pettersson has extracted a series of facts of the greatest interest and importance, especially when taken in conjunction with similar records of the success or failure of the fisheries in the transition area. The fish are carried in by the under-current of salty water, of which part comes from the Norwegian Sea bringing with it the more northern fishes such as ling and certain races of herring, and the other part from the North Sea, and with this some more southern fishes, mackerel, whiting, hake and other races of herring, while even fishes from the Bay of Biscay and the Mediterranean occasionally appear. It had been known for many years that the "north-fishes" came in the winter and the "south-fishes" in the summer, when Professor Pettersson showed, some years back, that this was to be explained by the presence of a similar variation in the relative strengths of the two streams which together make up the inflowing under-current. There is a regular rhythm, or "pulse-beat", as Professor Pettersson aptly describes it, in the strength of the currents, a rhythm due to tidal forces,

the result of the attraction of the water by the sun and moon.

As a result of the slightly irregular shape of the earth and the different positions it may take up relative to the sun and moon, many different tidal periods are produced, and in the Kattegat daily, half-daily, monthly, yearly and even longer tidal periods have been identified. The supply of fish, and so the occurrence of the fisheries, are closely bound up with these tidal periods. The mackerel come during the yearly ebb period in the summer months, while the herring shoals appear during the autumn and winter when the currents are at their strongest. But—and here we come to the most interesting feature of Professor Pettersson's work—the herring-fishery in the transition area is subject to fluctuations on a far greater scale and at much longer intervals. Owing to the great importance of the herring-fishery continuous records are obtainable of its ebb and flow from the tenth century onward. An examination of these records shows that from 971 A.D. to the present day there have occurred a succession of nine rich herring-fisheries which were alternately large and small, the former lasting for between twenty

and thirty years and the latter for between fifty and seventy years. This remarkable fact is to be explained, so Professor Pettersson believes, by the presence of tides with a regular periodicity of one hundred and eleven years.

The differences in the length of the different herring-fisheries are due to the different relative positions of the earth, moon and sun. The most favourable conjunction of all occurred towards the end of the Middle Ages and allowed the herring to pass further into the Baltic than they have ever done since. This was the period of the greatness of the North German towns known as the Hanseatic League, no small part of whose importance was due to their exploitation of these herring shoals. Thus we find ocean currents influencing not only fish and fisheries but, through them, the course of history; for with the waning of the herring-fishery at the end of that period the importance of the Hanseatic League declined.

The last period of the Swedish herring-fisheries extended from 1876 to 1897 and was ended, as Professor Pettersson points out, by a great change in the nature of the water entering the Kattegat. The herrings are

brought in by the current which comes down from the coast of Norway, but in 1897 there was a great influx of water from the Atlantic which completely blocked the Norwegian current and so prevented the herring from entering the transition area. This Atlantic water is warmer than the Norwegian current, and it is a fact that the coldest winters, when ice often forms in the Kattegat, have always occurred during the great herring fishery periods. The milder winters come with the warmer Atlantic water and with a great scarcity of herring. The fish which cannot enter the Kattegat remain along the coast of Norway, and so the Norwegian herring fishery is greater during the periods of scarcity in the Kattegat and transition area generally.

The story which Professor Pettersson tells us, with a far greater wealth of detail than can be reproduced in a short article, is both fascinating in itself and also full of encouragement to all interested in marine research. By his patient examination of the hydrography of the transition area he has been able to explain the hitherto mysterious waxing and waning of the herring fishery in that region, and feels able also to prophesy with

some degree of accuracy the date and duration of the next great herring fishery. There can be no one who will deny the great economic importance of such "prior information"; while it is a striking example of the way in which, slow and tortuous though the process be, the underlying causes of fish migrations, upon which the success of the fisheries depend, are being discovered.

3. *Fishery Research Since the War*

While all science transcends the bounds of nationality, in no branch is this more obviously the case than in marine research since, with the exception of a strip three miles wide round the coasts, the sea which is the subject-matter of the science is itself international, and all the great fisheries are situated in international waters. The need for co-operation in the investigation of the abnormally rich fisheries in the North Sea by all the nations which participated in them was long ago recognized and gave rise, at the beginning of the century, to the formation of the International Council for the Exploration of the Sea. The participating countries were Great Britain, Germany,

Holland, Belgium, Russia, Denmark, Norway and Sweden, while the United States joined later; the headquarters being situated at Copenhagen. Untii the outbreak of war, this central authority performed a most important service by co-ordinating the scientific activities of these countries in so far as they had any bearing upon marine research and directing them into the most useful channels. The War, although it resulted in the withdrawal from the Council of Germany and the United States and later of Russia, did not entirely check its work, and it was maintained as an active organization until, at the invitation of the British Government, it reassembled, less the three retired countries, but with the addition of France and Finland, at London in March, 1920.

At that meeting a new programme of work, which included hydrography, statistics, and research on food fishes and on the microscopic life at the surface of the sea, or plankton, was drawn up, and further investigations in the English Channel and other parts of the Atlantic slope, an extension of the original range of activities, and into problems connected with freshwater fisheries were planned.

The greater part of the work done by the Fisheries Department in this country is being carried out in co-operation with the Council, and as a part of its programme.

The War, however little else can be said in its credit, by applying drastic restrictions to the North Sea fisheries, did unquestionably lead to an increase in the stocks of fish, which before the War were showing signs of serious depletion. During the later years of the War and immediately after it the catches were greater, and the size of the individual fish distinctly larger, than in 1913. As was to be expected, this increase was most marked in the bottom living, or "demersal", fish, of which the flatfish are the most important examples, since, owing to their habits and restricted movements, they are more completely at the mercy of the trawl than the more active and further ranging fish which live nearer the surface. Thus in the case of plaice, with which the most important of the English investigations have been concerned, the average catch in 1919 was about double that of 1913, while the proportion of large fish had greatly increased. Small plaice were rare and often absent in many parts where before the War they had been

abundant, and were found to be restricted to grounds nearer the coast. This fact, together with the discovery that there had been a decided slowing down in the rate of growth, since fish were smaller for their age than before the War, could only indicate a definite overcrowding. Although by 1920 there were signs of a return to pre-war conditions, yet proposals for plaice protection need the most careful consideration in view of the fact that too rigorous protection would lead, apparently, to overcrowding and reduction in the rate of growth, and so to a diminution in the possible yield of any area. The Fisheries Department recommend a transplantation on a large scale of young plaice to the ideal conditions which prevail for them on the Dogger Bank—in one year young plaice will increase their weight by four and a half times in this region, while similar fish left on the coast will only double their weight—and the restriction of fishing in areas where the rapidly growing young plaice are present in the largest numbers.

While it is always difficult to determine the exact conditions which prevail in any part of the sea, this is particularly the case with regard to the sea bottom. Plaice are

bottom-living animals and find their food among the other creatures which live at the bottom of the sea and which provide a source of fish food second only in importance to the plankton, which furnishes food for the surface dwelling fish such as the herring and mackerel. Although it was always possible with the aid of suitable dredges to obtain qualitative estimates of the inhabitants of the sea-bottom in any particular area, it was not until the invention by a Danish zoologist, Dr C. G. J. Petersen, of a bottom-sampler, or "grab", which bites out pieces of definite area from the bottom of the sea, that any quantitative estimation of the bottom fauna could be made. This apparatus, though not perfect, has proved of great value, and has demonstrated the presence of definite groups, or "communities", of animals in different areas and at different depths.

Extensive use of this method of investigation has been made in order to determine the nature of the bottom fauna on the Dogger Bank and the possibility of its being able to provide sufficient food to support the transplanted plaice. Animals at the sea-bottom have not a general distribution as might be

imagined, but apparently live in isolated areas, though often in vast numbers within those areas. Two bivalve molluscs, *Spisula* and *Mactra*, both of which resemble small cockles and which together constitute one of the principal sources of food for plaice and haddock, show this type of distribution very clearly. On the Dogger Bank *Spisula* was found in patches as extensive as fifty miles by twenty and at a density of anything from one thousand to eight thousand to the square metre, while *Mactra* occurred in patches of fifteen to twenty miles in diameter and up to seven hundred per square metre! Surely ideal feeding grounds for plaice.

The hydrography and plankton of the North Sea are especially studied in connection with investigations into the cod and herring. The great susceptibility of fish to any change in the physical conditions of the water with which they are surrounded and its influence on their abundance in any year—on which, of course, depends the success of the fisheries of that year—is shown as the result of an examination into the causes of the failure of the herring fishery in 1921. From the slightly higher temperature and the exceptionally high salinity of the water in the

southern part of the North Sea, it was found that there had been a great inflow of " Atlantic water " into this region during the early months of that year. A striking confirmation was provided in the plankton investigations of the same year, which revealed the presence of enormous numbers of pteropods—small and highly specialized snails which live at the surface of the sea—and also certain jelly-fish and other animals, all of which are typical Atlantic forms, and are never present in the North Sea in a normal year. There can be little doubt that these abnormal conditions were responsible for the failure of the herring fishery, since similar conditions prevailed in 1905, which was also a bad herring year. In exactly what way the herring are affected, however, remains still to be discovered.

It has only been possible above briefly to indicate a few of the more interesting lines of research which are being carried out on the food fishes. Although a great amount of valuable information has been obtained by these researches, the most important fact of all is that scientific investigations have now been set more firmly than ever on their feet, and that the groundwork is

being laid of a thorough examination, and so eventually a proper conservation, of these fisheries which are by no means the least valuable portion of our national heritage.

4. *The Bed of the Ocean*

The ideal and purpose behind marine biological research is an eventual "farming of the sea". But just as it is impossible to farm the land successfully until the nature of the soil and of the climate and their effects on various crops and animals are known, so it will be impossible to farm the products of the sea until the corresponding knowledge is gained. To obtain this is no easy matter; the sea is too immense and too obscure in its vast depths lightly to yield its secrets to the curiosity of science. Oceanography is a young science actively engaged in collecting information about the structure, habits and development of marine animals and plants; about the conditions, chemical and physical, of the sea; and about the nature of the sea-bottom; and slowly, beginning to discover the interactions of the one on the other, and so free the first threads from the

massed tangle of interwoven strands. And of these threads perhaps the most disentangled, owing to its nature, concerns the nature and inhabitants of the bed of the ocean.

The study of the deposits which cover the bottom of the sea formed the greater part of the life-work of the great Scottish oceanographer, Sir John Murray, and it is to him that we are indebted for most of our knowledge on this subject. By an exhaustive study of samples of the sea-bottom obtained on the voyage of the *Challenger*—the first and greatest of all expeditions for marine research, whose cruise from 1872 to 1876 laid the true foundation of oceanography—and on later expeditions, he was able to divide the ocean deposits into two main parts. In deep or shallow water near the land he found that they consisted largely of material washed down by the rivers from the land or worn away by wave action, whereas the bed of the ocean far from the land was covered with a soft "ooze" composed of matter which had sunk down from the water above. The nature of the deposits near the coast varies according to the nature of the land; for example, it may be of coral or volcanic

origin, while in the open sea the composition of the oozes varies greatly in relation to the latitude and depths of the various oceans.

The only material which can drop from the upper layers of the sea on to the bottom consists of dead animals and plants or of volcanic dust which falls into the sea from the air. The vast bulk of life in the sea is composed, not of the large and active creatures such as fish, whales or squids, but of microscopic plants and animals which float near the surface and make up the all-important plankton. It is their skeletons, for the soft parts quickly disintegrate or are eaten by larger animals, which form the great proportion of the deep-sea deposits, and according to the relative abundance of the various types of skeleton so we can distinguish between the different oozes. Particularly around the poles there is a great abundance of microscopic plant life; each individual is enclosed in a delicate case of silica, and as the plants die there is an unceasing downward rain of these skeletons, which accumulate to form the chief constituent of the deposits on the bottom.

Although there is an abundant flora in the plankton of the temperate and tropic seas,

there is a much greater proportion of animals, so that it is the delicate limy skeletons of minute protozoa or transparent swimming snails, or " sea butterflies ", which are most characteristic of the bottom deposits in these regions. There is a limit, however, to the depth at which these limy deposits are found, since the greater the depth the more water the skeletons have to fall through and the more lime is dissolved ; hence the quantity of lime on the sea-bottom gradually diminishes and at a certain depth ceases altogether. Below this point only the silicious skeletons of certain of the animal plankton are found ; while at the greatest depths of all (below 2,700 fathoms) even the silica is dissolved, and the deposits then consist of what Murray called " red clay ". This is a true clay which has been formed by the prolonged action of sea water on volcanic dust. Like the silicious deposits, it is present at all depths, but is usually masked by the deposits of animal and plant origin.

Although the actual substance of the sea-bottom has not the same significance as the soil on land, since the seaweeds do not root in it but merely attach themselves to it and obtain all their nourishment from the

water, yet it has considerable importance. In the first place it is of use to the bottom living animals, which may crawl on the surface, burrow into it, or attach themselves to it. The nature of the bottom—mud, gravel, sand or rock—is clearly of the first importance to them. Secondarily it forms a reserve of substances of which the sea can only carry small quantities in solution but which are of vital importance in the economy of marine life. Of such lime and silica are the most important, since, as we have seen, they form the skeletons of the great mass of animals and plants. If there were not a constant reserve of these in the bottom deposits the sea would soon be denuded of them; even as it is the amount of silica in solution near the surface of the sea is greatly reduced in the spring and early summer when the plant life is increasing most rapidly. In the winter, when the flora is much reduced and there is a mixing of the waters at various depths and fresh dissolution of silica from the bottom, the surface waters again become fully charged with silica.

Extensive investigations of the fauna of the sea-bottom by means of dredges and trawls have shown that it varies greatly in different

regions. This is chiefly the result of depth, temperature and salinity and of the interactions of these three factors. The few observations which have been made there reveal that there is animal life, and of a unique type, even at the greatest depths. The Norwegian Sea has probably been the most thoroughly investigated, and there we find two distinct faunas, one living in the arctic regions where the water has usually a temperature below "freezing point" and is very salt, and the other in the boreal regions where the water, under the influence of the Gulf Stream, is several degrees warmer and the salinity varies more. There is also a fauna intermediate between these and known as the boreo-arctic fauna. In each case different animals are found at varying depths, so that we can conveniently distinguish between littoral, sublittoral and continental deep-sea zones, with limiting depths of about one hundred, five hundred, and three thousand feet respectively, and each with a characteristic fauna. Finally, within these zones again there are distinct communities of animals, many very diverse species being always found living together. The discovery of these associations is one of the most

notable contributions to science made by the Danish Biological Station; it is undoubtedly of the first importance, and the scientific staff of the English Ministry of Fisheries is continuing similar work in the North Sea.

It may seem at first sight as though a knowledge of the shell-fish, worms, star-fish, and the like which inhabit the sea-bottom is of quite secondary importance, but this is far from being the case. All life is a unity; there are no bounds to the interactions, obvious or concealed, of the different groups of animals and plants. The shellfish and worms, in particular, form the most important part of the food of the bottom-living food fish, such as the many species of flatfish, the skates and the haddock; and the Danes have recently produced very illuminating figures which show that the success or failure of the fisheries in any year is largely dependent upon the numbers of the other members of the bottom fauna, especially shellfish, in that year. We are only at present on the fringe of a great and complex problem, but such results as these tell us that we are working on sound lines, and that our end, though still far distant, is being approached.

5. *Plankton*

Marine life has been conveniently divided into three great categories. There are the animals and plants which are permanently attached to the sea-bottom or, in the case of the animals, which crawl about or burrow into it—such as the seaweeds, anemones, corals, molluscs and worms—which are known collectively as the benthos. The animals which swim freely in the sea, and are usually large and always active, like the fish, whales, seals and squids, are called the nekton. All these organisms are well known to everyone, but there is a third group, which includes a vast multitude of animals and plants which float or drift at, or very near, the surface of the sea, which is often entirely overlooked because the majority of its members are of microscopic size. This is the plankton and, though our knowledge of it is of recent date and still very imperfect, there can be no doubt as to its vital importance in the economy of marine life as the prime source of food in the sea, a fact which becomes increasingly obvious with the development of marine biological research.

Many very diverse organisms go to make up the plankton. There is a dense flora, or phytoplankton, consisting for the most part of microscopic plants known as Diatoms, but including the well-known *Sargassum*, one of the largest of the seaweeds. The fauna, or zooplankton, includes types of all the great subdivisions of the animal kingdom. The Protozoa, or unicellular animals, are represented by the Foraminifera and the Radiolaria, whose empty shells form a great part of the deposits on the bed of the ocean, and by the more delicate Flagellates and green Peridinians. The planktonic Coelenterates are larger, and therefore more widely known; they consist of the jellyfish, the sea gooseberries (Ctenophores) and the Siphonophores, of which the Portuguese man-of-war is one of the largest. All star-fish and sea-urchins undergo a "larval" stage, during which they swim freely at the surface of the sea, before they develop into the adult form. The same is true of the majority of the worms, molluscs and tunicates, though all three groups include species which spend their entire life at the surface of the sea. The sea-butterflies (Pteropods), which occur in vast numbers in some parts of the ocean and

form the principal food of the baleen whales, are an example of highly specialized molluscs which are permanently planktonic. Practically all the Crustacea—the great group which includes the crabs, lobsters, shrimps and barnacles—are planktonic at some period in their lives, while many of the smaller species are permanently so and constitute the most numerous, as well as economically the most important, section of the zooplankton. The eggs and early stages of many fish are present in great numbers at certain periods. The plankton can thus be divided into two groups —temporary, where only a portion of the animal's life is spent at the surface of the sea, and permanent, where the entire life is planktonic.

While many members of the nekton, such as the fish, display definite migratory movements in search of food or to and from their spawning grounds, the animals of the plankton do not show this "directed" activity; although many of them possess the power of movement on a small scale. Instead they drift passively on the surface of the sea and are carried over vast areas by tidal streams, currents and wind drifts. The plankton is much more directly affected by physical

changes in the sea and atmosphere than are the nekton and benthos, which live under very uniform conditions. The temperature of the surface water varies greatly between winter and summer, being, in Europe, lowest in March and highest at the end of July and in early August. The intensity of the sunlight, which is of vital importance for the plant life, is another variable factor, greatest in June and least in December. The salinity of the ocean, which also varies, is at its lowest during winter and early spring when most fresh water enters the sea. Finally, there is a variation in the amounts of certain chemical substances present, which is the most important factor of all.

As a result, very largely, of the interaction of these different factors, there is a well-marked procession of planktonic life throughout the year. During the winter there is a great scarcity of plankton, though towards the end of March the temporary plankton, in the form of fish eggs and the early stages of many Invertebrates, becomes plentiful. The temperature and the intensity of the sunlight increase between March and June, with the result that the plant life, mainly Diatoms, multiplies rapidly until it reaches a

maximum in June, after which it falls off owing to the exhaustion of essential food constituents. The Peridinians, which also contain green chlorophyll and so are dependent on sunlight, are most numerous in June and July. During midsummer, by which time the majority of the temporary plankton have changed into their adult benthic or nektic forms, the permanent zooplankton increases. It is a matter of common observation that jelly-fish are most plentiful at this period, and the same is true of the other Coelenterates and of the minute shrimp-like Crustaceans which are everywhere abundant from May to November. The Diatoms again multiply in September and October, but afterwards decrease, and for the same reason as before. There is a renewed abundance of eggs and temporary plankton in October and November.

The temporary plankton is much more independent of physical factors in its distribution than the permanent plankton. Although it arises in the localized areas in which the adults lay their eggs, it can be distributed over wide areas and tolerates a great range of physical conditions. To quote a conspicuous example: the young eels hatched out in the Gulf of Mexico experience

a great variety and range of conditions during the three years they spend at or near the surface of the Atlantic, before they reach the mouths of the European rivers in which they are to spend their adult life. Although the permanent plankton can be transported long distances by the great ocean currents so that there is a considerable mixing of its constituents, yet, with some exceptions, it can be divided into oceanic and neritic species, the former living normally outside the hundred fathom limit, and the latter being particularly characteristic of shallow coastal waters.

Just as on land, the marine fauna depends for its food entirely upon the presence of plant life. Upon the numbers and distribution of the Diatoms and other constituents of the marine flora, therefore, depend the numbers and distribution of the zooplankton, and so of the larger animals of the nekton which feed upon it and are themselves the food of still larger animals. But the abundance of the Diatoms is itself dependent on a number of factors which must now be considered since they are *the* vital conditions on which depends all life in the sea.

The temperature of the sea is very

important. As a rule increase in temperature increases the rate of multiplication of the Diatoms, although in some cases this is brought about by a mere change, not necessarily a rise, in temperature. The intensity of the sunlight is also of the greatest importance. The green chlorophyll of the plants can only form starch out of carbon dioxide and water with the aid of solar energy, so that the phytoplankton is much less numerous in a spring in which there is little sunshine, than in one in which there is ample. Since the greater the activity of this "photosynthesis", the more carbon dioxide—which in its combination with water is an acid—is taken from the sea, we are able to form some estimate of the degree of multiplication of the Phytoplankton by measuring the alkalinity of the water, which increases in proportion as they increase. When, on the other hand, the zooplankton begins to increase, a little later in the year, the sea becomes more acid on account of the carbon dioxide which the animals excrete.

Naturally the limit of increase of the phytoplankton must depend on the supply of food substances. The most important of these are carbon dioxide, inorganic nitrogen

compounds, phosphates and silica. As soon as the supply of any of these is exhausted, the Diatoms can no longer multiply and begin to decrease. It was believed until lately that the most important of these limiting factors was the supply of nitrogen compounds, but recent research points to the exhaustion of the phosphates as being at least as important a cause of the summer decline of Diatoms and Peridinians. That these substances are used up by the plankton is forcibly demonstrated by the fact that it is only the surface waters which are depleted of them; they are always present in the underlying water. The presence of excessively minute amounts of some accessory food substance—some "vitamin" possibly—of whose nature we know nothing, is also essential. It is impossible to rear Diatoms in artificially prepared sea water unless a minute quantity of ordinary sea water is also added. Finally, the various animals and plants of the plankton act upon one another until an essential balance is achieved.

It is not easy to estimate the absolute density of the plankton. As the methods of investigation have become more exact, the estimated figures have increased greatly. The

larger organisms can be collected from the sea in " tow-nets " of fine silk, and an average of between two and three per cubic centimetre is found. But if samples of sea water are taken and the more minute organisms collected and counted, an average of fourteen or fifteen is obtained : while by growing the organisms contained in samples of sea water in special culture media, a *minimum density* of 464 separate species in each cubic centimetre has been proved. During the period of the great increase in the Diatoms in the spring, it has been calculated that a crop of some ten tons of moist plant organisms is produced per acre of sea.

Shell-fish

6. *The Development of the Shell-fish Industry*

The period of the great material prosperity of Great Britain, which began at the Industrial Revolution and ended in the war, led to an ever-increasing reliance on food supplies of foreign origin, while the food-producing

capacities of this country were allowed to decrease to a corresponding degree year by year. Under the pressure of a great necessity, a considerable amount of lost ground was recovered during the war, but since then there has been a falling back to the old state of affairs. It seems likely, however, that a shifting of the balance of the nation's activities from industry to the production of food will be necessary if Great Britain is to re-adjust herself to post-war conditions.

A most striking case of neglect of a valuable source of food is furnished by the small extent of the shell-fish industry in this country (the term "shell-fish" being here used to include molluscs only and not, as in the commercial sense, crabs, lobsters and the like). With the solitary exception of the oyster, shell-fish are absolutely ignored as food by all but a section of the working classes. This is far from being the case on the Continent or in the maritime regions of the United States, where many kinds of shell-fish are a popular article of diet with all sections of the population. All shell-fish have the property of storing great quantities of glycogen, or "animal starch", and of fat, which renders them in the highest

degree nutritious, and they are, moreover, rapidly growing and prolific animals capable of extensive fishing which could be greatly increased by judicious farming.

An important development in the scientific investigations of the Ministry of Fisheries during and since the war has been the increased attention that has been paid to shell-fish. The following extract from an official report will give some idea of the potential food value of the mussel, which, together with the oyster, the cockle and the scallop, is the most important of our shell-fish. "It has been calculated that an acre of the best mussel ground will produce annually 40,000 lb. of mussels, equivalent to 10,000 lb. of mussel meat with a 'fuel' value of 3,000,000 calories and a money value of about £250, and this at the cost of practically no capital expenditure and only such labour as is involved in transplantation to prevent overcrowding, and to secure the best conditions for growth and fattening. No known system of cultivation of agricultural land can produce corresponding values in the form of animal food. The average yield in beef of an acre of average pasture land is reckoned to be 100 lb., equivalent to 120,000 calories and valued at,

say, £7 10s. The yield of rich fattening pasture may be as high as 190 lb., equivalent to 480,000 calories, and valued at, say, £14."

Any development of the shell-fish industry is dependent upon the solution of the two problems of purification and cultivation, of which the former is the more pressing but the latter the more fundamental in the long run. The mussel beds are situated for the most part in estuaries, and many of them are seriously contaminated with domestic sewage from the towns which border the rivers. Bacteria are freely taken in by mussels while they are feeding and, though the mussels themselves are quite unaffected, they can become in this manner a possible medium for the dissemination of typhoid and other pathogenic bacteria. The danger of infection from the consumption of shell-fish has undoubtedly been one of the chief causes of their neglect, and every effort must be made to insure the purity of all shell-fish sold as food if the public is to be persuaded to alter its by no means unjustified prejudices. The best remedy, and one which in all probability will eventually be applied, would be the prohibition of any discharge of sewage near the

shell-fish beds. But for the present, in view of the fact that pollution is so extensive and the cost of prevention correspondingly heavy, either the sale of polluted mussels has to be stopped in the interests of public health or some means found of cleansing them and so rendering them safe for human consumption.

In 1912, owing to an adverse bacteriological report, the Fishmongers' Company banned the sale of Conway mussels, which had provided a livelihood for a considerable number of fishermen. Owing to the initiative of the Corporation of Conway, investigations were commenced, which were later taken over by the Ministry of Fisheries, into the possibility of cleansing the mussels. It was found that this was impossible under natural conditions; it could only be satisfactorily accomplished under artificial and carefully controlled conditions. Especial tanks were constructed and, as the result of prolonged experiments, the following procedure was instituted and has been continued, with the improvements suggested by experience, ever since. The mussels are spread two deep on wooden grids in shallow tanks and thoroughly hosed in order to cleanse the outside of the shells.

Sea water which has been sterilized by the addition of chloride of lime, any free chlorine being afterwards converted into common salt by the action of sodium thiosulphate, is then run in, and the mussels are left in this water for one day. During this period, they open and discharge the contents of their stomachs, including any bacteria they may contain. The water is then run off and the tank filled a second time with sterilized water and for a similar period. Finally the shells are thoroughly sterilized with chlorinated water and the cleansed mussels are packed in sterilized bags and are ready for the market.

This procedure, which was first instituted on a commercial scale in 1916, has proved entirely successful from every point of view, there have been no further complaints of pollution and the mussel fishery has regained its original dimensions. The expense incurred in the upkeep of the tanks is met by a fixed charge for each bag of mussels cleansed. Obviously, if the cleansing operations are not to be an expense to the community, they can only be instituted where there is a fishery large enough to meet the costs. Accordingly, many of the small fisheries which have been

condemned cannot be treated in this manner, although a second cleansing station has recently been erected by the Ministry at Lympstone on the River Exe in Devonshire, while exhaustive surveys of the principal mussel beds with reference to their potentialities and degree of pollution have been made.

The problem of the purification of oysters has also been attacked. These animals, though structurally very similar to mussels, are both less liable to take in bacteria and also more difficult to purify when they are polluted. They will only function freely, and so expel the contents of their stomachs, when the water is above a certain temperature, which is distinctly higher than the minimum temperature at which mussels will function. No satisfactory system has yet been devised for the purification of oysters on a commercial scale, although it can only be a matter of time before this is accomplished.

Extensive as are the mussel beds, they can be greatly increased and the yield improved in both quality and quantity by judicious farming and by transplanting mussels to favourable grounds, where they will have ample food and protection. Mussels have been cultivated in this way for centuries along

the coasts of Europe in order to meet the great demand which exists for this kind of food. In the same way, clams (large shellfish, two or three times the size of a mussel) are farmed along the coasts of the United States, while oysters, of course, have been cultivated since classic times, and at the present day the rearing of oysters forms an important industry in France, the United States and Japan. In this country, although the oyster beds are cared for, they are left to replenish themselves naturally, which, since the oyster is an uncertain spawner, is far from satisfactory. In bad years young oysters or "spat" are purchased from the French cultivators.

As the result, very largely, of an accidental fall of "spat" in one of the mussel purification tanks at Conway in 1918, the Ministry were led to extend their investigations to the breeding of oysters. It was hoped that in this way a sufficient number of English reared "spat" could be obtained eventually, which would insure a continuous supply for growth and fattening on the oyster beds. Advantage was taken of the fact that the mussel purification tanks were not in use during the summer months when the oysters

spawn, to attempt breeding experiments on a large scale in them. The French method of collecting "spat", which consists of placing long curved tiles covered with lime in the tanks with the spawning oysters, was employed. The small oysters which settle on the tiles are detached, when a suitable size, by flaking off the lime beneath them. The results of these experiments have been somewhat baffling; although great numbers of "spat" have been obtained on several occasions, in other years, for no obvious reason there have been little or none. The exact conditions needed for the breeding on a commercial scale of oysters in these artificial surroundings are still unknown, but there is no reason why they should not be discovered in time as a result of the present researches. These investigations, it may not unreasonably be hoped, will be the beginning of a scientific study of the edible shell-fish of our coasts, having as its ever-present aim their development and intensive cultivation.

7. *Oyster Cultivation in France*

Among the various attempts at agriculture, or farming, of the products of the sea, none

has been more successful or attained greater dimensions than the cultivation of oysters, which to-day forms one of the principal industries along the west and north-west coasts of France.

About the middle of the last century, as a result of intensive dredging, the natural oyster beds on the French coasts—which during the earlier part of the century had been so extensive that in 1843 it is recorded that seventy million oysters were dredged from the beds in the Bay of Cancale, on the North Breton coast—became depleted to such an extent that in 1868 not more than about one million were taken in the same region. The same thing happened in the other natural oyster beds, and the French Government were compelled to take action and to restrict greatly the dredging of oysters in order to allow the beds time to restock themselves. At the same time investigators were appointed to find out whether the beds might not be replenished by artificial means by methods similar to those practised by the Romans, and ever since continued, in Lake Fusaro in the south of Italy. It was discovered that oysters could be transplanted to new localities, where they often grew and

bred more successfully than in the original habitat, while the young oysters could be collected on bunches of twigs fastened in the water near the spawning adults.

These encouraging results led to a widespread attempt at oyster cultivation, both in the south and west, under the inspiration of a certain Professor Coste, of the College of France, in Paris, who had studied the primitive Italian methods and been struck by their possibilities. After early successes, however, misfortunes, due principally to ignorance of the conditions under which the oyster —an exacting and fastidious animal—can breed and feed, befell the young industry, and Coste died, having apparently accomplished nothing. But in reality he had accomplished a very great deal, for as knowledge increased, often as the result of bitter experience, the best conditions for oyster cultivation were discovered, and it was found that, while one district was ideal for the breeding of oysters, they might grow and fatten more rapidly in another which had a better supply of food. Accordingly, each district developed that side of the industry to which it was best fitted, and so gradually grew up the great modern industry.

While oyster culture, to greater or less extent, is carried on practically everywhere along the west and north-west coasts of France, there are three principal centres of the industry. The first of these is at Arcachon, some fifty miles south of Bordeaux, the second at Marennes, near Rochefort, and about midway between Brittany and Bordeaux, and the third at Auray, on the south coast of Brittany. A study of the methods carried on at these three places—all quite distinct—will give a very clear idea of the nature and organization of the oyster farms.

Arcachon, the centre of the most extensive oyster beds in France, lies on the shores of a wide and shallow bay which communicates with the sea by a single narrow opening, through which the tide races with great force. At low water the greater part of the bay is exposed, and can then be seen to be covered everywhere with oyster parks. Each park is surrounded by a low wall strengthened with stakes and twigs driven well in, and possessing on the outer side, and sometimes on the other sides as well, a palisade of stakes, eight or ten feet high, the tops of which, when the tide is in, are the only indication of the presence of the parks below.

The surface within the parks is kept clean and smooth and free from the enemies of the oyster, such as crabs, whelks and starfish. On this clean firm surface, which is covered by the sea except at dead low water, are laid the oysters and there they grow and, more important still, there they breed, for Arcachon, together with Auray in the north, is one of the few places which provide perfect conditions for the breeding and collection of young oysters.

Every female oyster may produce a million or more eggs each time she spawns, which she may do more than once every summer, and, moreover, in the case of the "native" or flat oyster (*Ostrea edulis*) every oyster is alternately male and female, so that every individual produces its quota of spawn during the summer. In the case of the Portuguese oyster (*Ostrea angulata*), with which the beds at Arcachon are now almost exclusively stocked, the sexes are however normally separate. The eggs are fertilized while still within the body of the female, and they undergo the preliminary stages of development while still between the shell valves of the parent from which they emerge, a week or ten days after hatching, as minute shelled

"larvæ" which swim about by means of a crown of minute and rapidly moving hairs, or "cilia", which can be projected at will from between the open valves of the shell. After a few days of swimming, the larval oyster settles or, in the words of the oyster cultivator, "the spat falls", and changes almost immediately in shape and structure until it comes to resemble the adult in all save size. It is at this period in their life history that the mortality among oysters is highest, for if the right surface for fixation is not provided the young oyster dies. What they need is a firm clean surface; the spat cannot settle if the bottom is covered with mud or slimy stones. The most important point about oyster cultivation is the provision of the suitable surface on which the spat can collect, so that the tremendous waste which inevitably occurs if the process is left to Nature is obviated.

In Italy and parts of France this surface is provided by adopting the old Roman device of using bundles of twigs fastened together by rope and firmly secured in the sea; in other places clean empty shells, known technically as "cultch", are scattered over the beds; but the modern method,

which is now widely adopted, especially in France, consists of employing as collectors roofing tiles, some 18 inches long and 6 inches wide and curved in the form of a third of a cylinder. These are coated with a mixture of sand and lime, and are arranged, alternately one way and then the other, but always with the concave side downwards, in large wooden containers. These are put out about low water line so that they are covered with water for the maximum period.

The collectors are placed in position about the middle of July, when the oysters begin to spawn, and there they are left till the following spring. The larvæ carried by the retreating tide from the parent oysters in the parks are washed against the tiles and, finding an ideal surface for the purpose, proceed to settle in large numbers, especially on the protected underside. In a good year as many as 200 may settle and grow on a single tile. Immediately after settling the young spat cement themselves firmly to the surface by the left shell valve and then proceed to feed and grow at great speed. Less than a millimetre across when they first settle, they may attain a diameter of an inch or more in the following spring, when

the collectors are taken in and the adhering oysters are removed from the tiles by flaking away the lime beneath them. Without the lime the tile would have to be broken in pieces to separate the young oysters, for it is impossible to remove them from any surface to which they are directly attached without breaking the shells.

The small oysters so obtained are too delicate to be placed directly in the parks, where they would be in grave danger of being smothered by fine particles of mud or sand or being eaten by one of their numerous enemies. Instead they are transferred to large flat cages or trays, which measure some 6 by 4 feet, and are usually about 6 inches deep. They are made of wire netting or perforated metal and stand on short legs, and are known as " ambulances " or " caisses ostreophiles ". With their contained oysters these are placed in special parks where they are uncovered at low water, when the contents are examined, and any dirt or intruding animals removed. As the young oysters grow they are thinned out, some being transferred to new cages and the largest being thrown into the parks, where they remain until they have attained marketable

size, which usually takes two years, when they are collected in network bags, and are then sent away to be sold.

The extent of the beds at Arcachon is most impressive; the parks stretch as far as the eye can see along the shores and on the sandy island which appears in the middle of the bay at low water. Many thousands of people are engaged in the industry, the number of oysters exported each year varying between 300,000,000 and 500,000,000.

Besides the young, or seed, oysters which are kept and fattened at Arcachon, many millions are exported or sold to French cultivators or "éleveurs", especially from the district around Marennes and La Rochelle. In that region the coast is very low and muddy, and the spat oysters obtained from Arcachon are cultivated in shallow basins or "claires", which are dug out of the mud, the bottom being left very uneven so that it resembles a ploughed field. The claires may be near the shore or be several miles inland, and are filled with sea water at spring tides by way of canals. During the period between spring tides the water in the basins, which are very shallow, becomes warm and, as a result of the evaporation, abnormally salty.

In this way an ideal culture medium is provided for the growth and multiplication of the microscopic plants called diatoms on which the oyster feeds. Furnished with a positive surfeit of their favourite food, the oysters grow and fatten at an amazing speed and are soon ready for the market. Before they are sent away, however, they have to be cleansed both internally and externally, and so are placed for several days in brick tanks, known as " bassins de dégorgement ", which are filled with clean sea water. At the end of that time they will have passed out the contents of their intestines, which often include impurities of various kinds and also bacteria. They are then transferred to an adjoining, and empty, tank, where the shells are thoroughly scrubbed, and the oysters, now perfectly clean within and without, are finally packed up in wooden boxes and sent away to all parts of France.

In some of the claires at Marennes are produced the well-known green oysters. Oysters placed in these basins take up in the gills and other parts of the body a green colouring matter, which has become known as Marennin, from a particular diatom named *Navicula fusiformis* var. *ostrearia*. These

green oysters are considered a delicacy in many places and command a high price.

At Auray, on the south coast of Brittany, conditions are very different from those described at Arcachon and Marennes. The breeding of oysters is the principal occupation at Auray, but the adults live in the bed of the much-branched estuary, and are never exposed at low tide as at Arcachon. Moreover, the native, or flat, oyster, and not the long Portuguese oyster, is here cultivated. The collectors—of the same type as those at Arcachon—are arranged along the shores at extreme low water during the early summer and remain there until the following winter or spring, when the tiles are brought in and the young oysters scraped off. This is carried on in stone sheds, outside which are seen stacks of tiles from which the attached oysters have been removed and which are now awaiting a fresh coating of lime and sand preliminary to being placed in position again the coming summer. The seed oysters are either sold—at extremely high prices, for since the widespread and mysterious mortality which occurred among them between 1919 and 1921 the price of native oysters has risen very considerably—or reared at

Auray, being transferred first to the ambulances and later to the bed of the river, from which they are obtained, when a marketable size, by dredging, exactly as on the English beds.

The whole industry, in both its history and modern developments, forms an object-lesson in the value of applied biology, a lesson which we in this country, with our acute food problem and our often neglected or depleted oyster beds, would do well to take seriously to heart.

8. *Cockles*

In an earlier article some account was given of the shellfish industry in this country and the scientific work which had been conducted by the Ministry of Fisheries in this connection, particularly with reference to the cultivation and purification of oysters and mussels. It is encouraging to find that the development of this valuable source of food is still occupying a great deal of the attention of the scientific staff employed by the Ministry, while recently they have extended their investigations to the cockle.

The edible cockle is, no doubt, familiar to everyone. A good average specimen is about an inch long and has a rounded, white shell covered with small, rounded protuberances which enable it to grip the sand in which it lives. It is an extremely common shellfish, and is found along the coasts wherever there is a stretch of sand sheltered from currents and from the full force of the sea. It is especially abundant in the Wash, the Thames Estuary, Carmarthen Bay and Morecambe Bay, and in all these regions there are large and flourishing cockle industries.

The cockle lies normally buried in the sand so that one end of the shell is just flush with the surface, and it takes in sea water and the microscopic animals and plants on which it feeds by way of a short tube which projects from between the two halves of the shell in this region. Within the shell the food is collected by passing the water through an extremely fine sieve formed by a delicate lattice work of tissue which is covered by tiny, rapidly moving hairs which carry the fine food particles to the mouth. The water which passes through the sieve is rejected by way of a second tube which opens along side the first. As long as the cockle is healthy

and is not left high and dry at low tide this progress goes on so that a great deal of water is passed through the body, and any food it may contain collected, during the course of a day. The cockles can move about in the sand or on the surface by means of a very muscular "foot", a wedge-shaped organ which can be thrust out from between the two halves of the shell.

Since they depend for food on material which is carried in suspension by the sea water and not on anything they may obtain from the sand in which they live, it follows that, if the water is sufficiently rich in the kind of food they require, the sand may be so thickly populated with cockles that they lie almost literally "cheek by jowl". Thus in the beds on the Llanrhidian Sands in South Wales it is stated that, on the average, 357 cockles are present in every square metre of sand, while a complete bed of about 320 acres contains an estimated population of some four hundred and sixty-two million!

Like the oyster and the mussel, the young cockle spends a short period swimming about freely in the sea before it settles down to the quiet, sedentary life of its parents. The adult cockles appear to spawn mainly in

the spring and early summer, so that the bye-laws which enforce a close season from May till August on many of the beds with the hope of preserving the species would appear to have been framed without adequate knowledge of the habits of the animal. Some of these bye-laws are, however, in process of revision. The young cockles, after being spread far and wide in the sea, settle wherever they find a suitable bottom. In some places there are definite beds of these young or "seed" cockles, consisting of patches of soft, oozy mud quite distinct from the surrounding sand. In these "nurseries" the population is almost incredibly dense, the young cockles forming a compact layer just below the surface of the mud. As they grow, the boundary of the nursery extends on all sides over the surface of the sand, but in the centre the surplus population cannot be disposed of in this manner, and very many animals are forced to the surface. These are mainly carried away by currents, some to destruction but many of them to other parts of the beds which they help to restock.

As the cockle grows its shell increases, new layers being added round the outer edges. Since growth is more rapid in the summer

than in the winter, the shell is not added to at the same rate at all times of the year, and it is possible to estimate the age of a cockle by the number of rings on its shell in much the same manner as one judges the age of a tree by the number of annual rings in the wood. The speed of growth varies according to the conditions, especially the supply of food, but an average marketable cockle, about one inch long, is usually three or four years old.

The life of the cockle is not entirely unchequered. Its enemies amongst other animals are many and varied. Besides the attacks of a variety of parasites, it is eaten by starfish and bored into by the dog whelk—the two inveterate foes of all shellfish of this type—while many species of gull, and especially the black-headed gull, eat the young cockles. The undersized cockles which are rejected by the gatherers are frequently left exposed on the sand and " are practically presented to the gulls ". Great numbers of young cockles are probably eaten by flatfish which swim up over the beds when these are submerged. But far more dangerous than the attacks of other animals is the effect of physical agencies. Frost is the

cockle's worst enemy, and the population of a flourishing bed may be decimated by its action in a single night, while late frosts may kill vast numbers of young cockles, either in the swimming stage or when they have just settled. The other extreme of temperature is almost equally injurious, for cockles exposed on the surface of the beds during the summer are frequently killed by the heat. Storms may do great damage, the force of the breakers dislodging many of the cockles, which are thrown up in heaps on the shore at high-tide mark. Currents may do even more damage by washing the shellfish from a favourable to an unfavourable area, while streams or rivers, by a slight alteration in their course, may undercut the cockle beds and carry the whole population to destruction. The cockle gatherers themselves often do great damage to the cockles—and so to their own livelihood—by leaving the small, unmarketable specimens, in direct contravention of the bye-laws, at the mercy of the currents and the gulls instead of scattering them over the surface of the beds.

Cockles are gathered by a variety of methods. In some cases they are scraped up by hand or dug, but more often short-handled

rakes with large teeth or especially constructed scrapers consisting of sickle-shaped pieces of iron are employed. In the Morecambe Bay cockle fishery it is usual to tread the sand with bare feet in order to bring the cockles to the surface, while the " jumbo ", a wooden framework with a base board which rests on the sand, is used in some parts of Lancashire to force the animals to the surface. After they have been gathered the cockles are collected in heaps, washed, and then riddled through a standard sieve, only those animals which do not pass through the meshes being permitted to be sold.

Unlike oysters and mussels, cockles are seldom sent alive to the market; instead they are first boiled, or as at Leigh-on-Sea in the Thames Estuary, steamed. As a result of this treatment the soft parts come away from the shells, so that when they are sieved the soft parts alone pass through the meshes. After washing in clean water these are then despatched to the market either as they are or salted or else preserved in vinegar.

Although less rich in the valuable carbohydrate food material known as glycogen or animal starch than the native oyster, the

cockle provides an excellent and, like allied shellfish, an exceptionally well-balanced food. Moreover, on account of its habitat, it appears to be less liable to pollution than the oyster or the mussel, while its treatment with boiling water or steam further lessens the risk of bacterial infection. It is satisfactory, therefore, to find that the annual total of cockles landed in England and Wales has risen from 167,089 cwts. in 1923 to 300,721 cwts., having a value of some fifty thousand pounds, in 1925. Moreover, these figures do not include cockles gathered by casual collectors, who often outnumber the regular gatherers.

Up to the present, in spite of the large numbers of cockles gathered, there does not appear to be any diminution in the numbers on the beds ; but experiments by the Ministry of Fisheries have shown that it is quite possible to transplant cockles from regions where they are overcrowded and grow slowly to new and favourable localities where they quickly increase in size. There is thus not only good reason for expansion in the fishery, but apparently almost unlimited scope. But more attention must be paid to the demands of the market than in the past, when

considerable consignments of cockles have been imported from Holland merely because the gatherers in this country refuse to respect the market demand for large cockles, which the Dutch exporter is astute enough to do.

Profit and Loss from the Sea

9. *Pearls*

Alone amongst the gems used for the adornment of humanity the pearl is of animal origin; here alone do the interests of biologist and jeweller meet; even in the manufacture of artificial pearls an animal substance is used. Though the modern recognition of pearls probably originated with the Romans, they are mentioned in the ancient literature of China, India, Greece and most of the early civilizations. It is not unlikely that to seek the beginning of the use of pearls we should have to go back far before the birth of history, to the days when primitive man, living on shell-fish taken from the sea or rivers, found in them round beads whose

beauty and lustre awakened in him the dawning sense of beauty.

Though many bivalve shell-fish produce pearls, it is only in comparatively few that these are of the necessary size and lustre. The pearl oyster is a very different animal from the edible oysters of Europe and other parts of the world, all of which are members of the genus *Ostrea*, whereas the Ceylon pearl oyster and its relatives in Australia, the Malay Archipelago, the East Coast of Africa, the Persian Gulf and elsewhere, all belong to the genus *Margaritifera* and are more nearly allied to our common mussel than to the edible oyster. While, except in a few odd cases, no other marine shell-fish produce pearls of any commercial value, these are found in many kinds of freshwater mussels. The large mussels found in the rivers of many parts of the British Isles produce valuable pearls, and these have been extensively fished at various periods since the days of the Romans, who are reputed to have sought them in the Welsh rivers. Valuable pearls have been taken from mussels in the rivers of many parts of Europe, America and Asia.

The way in which pearls are formed has

always been a matter of speculation and, in the last two or three centuries, of much scientific investigation. The ancient Hindoos believed they were dew-drops which fell in when the oyster opened its shell and were later solidified by the heat of the sun ; another early theory attributed their formation to the action of lightning. For some hundreds of years now they have rightly been considered as pathological products, the result of some abnormal stimulation of the tissues. The cause of this stimulation is still a matter for discussion and further research. Blister pearls, which are fastened by a fine neck to the inside of the shell, and are often sawn off and used in cheap jewellery, may be produced by sand grains which have come to lie between the shell and the soft tissue or " mantle " which produces it, but there is little evidence that true pearls, formed inside the mantle tissue and quite distinct from the shell, are produced in this way. Parasites certainly cause pearl formation in many cases. This view, first advanced in 1554, has been proved by the finding of the mummified remains of different parasites in the centre or " nucleus " of many pearls. But it is not improbable that pearls are

often formed round tiny granules of waste matter produced by the animals themselves.

Whatever the nature of the irritating substance, the process of pearl formation is clear. The nucleus becomes enclosed in a little chamber in the tissues, and from the walls of this chamber is produced the pearl-forming substance—the same nacreous material which lines the inside of the shell and forms "mother of pearl". This is applied to the nucleus in regular layers, and gradually a round bead is built up, the lustre of which is due to the concentric stratification of the crystalline nacre of which it is composed.

The largest and most famous oyster fisheries in the world are those off the coast of Ceylon. The oyster beds are controlled and periodically inspected by the Government, and only when previous examination has shown that great numbers of oysters are present on the beds, is a fishery allowed. This is by no means a frequent occurrence, for there have only been thirty-nine fisheries since the beginning of the nineteenth century, and only six of these in the thirty-four years since 1891. After 1907, the last of a remarkable series of five consecutive fisheries,

there was a blank period of seventeen years. In the hope of discovering the cause of these great fluctuations in the population of the beds, and finding some means of ensuring a more regular fishery, a scientific mission, headed by the late Professor Herdman, was sent out by the Colonial Office in 1902. This enquiry revealed the fact that the oysters are in constant danger of death through silting sand, overcrowding, overfishing and the attacks of various enemies. Certain recommendations were made, but in spite of the subsequent carrying out of the majority of these and the continuation of scientific enquiries since, no real progress has been made in the effective control of the fishery, as is admitted in a recent report issued by the Government of Ceylon. The real difficulty is the inaccessibility of the beds, which, unlike those of the Portuguese oyster so successfully cultivated by the French in the tidal zone at Arcachon and elsewhere, are in comparatively deep water. It is always difficult, and in many cases impossible, to reproduce artificially natural conditions for animals which habitually live in deep water; one cannot collect and rear the young oysters, nor protect the adults.

The following words of an early writer[1] on the subject are but too true: "It is only when, in the infinite wisdom of the Creator of all things, the oyster brood descends upon the banks suited to nourish and support it —that it comes within our limited power to watch its advancing age, and to fish up the respective deposits in succession as they approach the proper age; not letting them rest on the banks until they die off, and the pearl is lost; and carefully abstaining from disturbing those that are too young to contain it".

When the beds are sufficiently stocked to warrant the holding of a fishery this fact is advertized in many different languages throughout the newspapers of the East, and on the appointed date divers, pearl buyers, speculators, shopkeepers, moneylenders and all manner of other people collect at the temporary town of Marichchikkaddi. The fishery, which lasts for anything up to three months, is controlled by the Government throughout. The divers go out every morning and all boats have to return at the sound of a gun fired about mid-day. The

[1] James Stewart, *An Account of the Pearl Fisheries of Ceylon*, 1843, p. 25.

oysters are landed and the catches at once divided into three equal piles, two of which are taken by the Government and later sold by auction, and the third by the divers. The washing out of the pearls is a slow, disgusting business, the oysters being left to rot, a process which is speedily hastened by the appearance of millions of fly maggots. After a week the largest pearls are picked out by hand; the smaller ones and the remaining filth are washed out of the shells and, in the course of a series of further washings, all the pearls are gradually collected.

The well-known Japanese culture pearl is a true pearl produced in the usual way, but the oyster is induced to form it by the introduction of a small body which forms the nucleus round which the pearl substance is laid. The process, the exact nature of which is a carefully guarded secret, takes several years.

The cheap artificial pearls have no connection with the oyster, but, curiously enough, provide another instance of the economic exploitation of the products of the sea. So long ago as 1656 it was discovered by a French rosary maker named Jaquin that a lustrous substance could be obtained from

the skin of certain fishes, and that very satisfactory imitation pearls could be made by coating with this substance beads made of wax or alabaster. From such humble beginnings has developed the large modern industry in imitation pearls. The "pearl essence" obtained from fish is really a waste product called guanin which is often deposited in the skin overlying the scales. After extraction in water and purification with ammonia a beautiful silvery suspension is obtained, the lustre of which is due to the reflection of light by the tiny crystals of guanin. The "pearls" are made by coating the inside of hollow glass beads with the pearl essence suspended in a suitable medium and later filling in the inside with wax; more satisfactory ones are obtained by giving a series of coats to the surface of solid beads of glass or porcelain. But an imitation pearl is quickly revealed as such by an examination of the holes, plainly not drilled, by the reflection given by the surface if of glass, or by the way the "pearl" substance can be dissolved off by suitable solvents if the beads are of the second type.

10. *Sponges*

It is not easy, perhaps, to realize that the sponges we use so frequently in daily life are in reality the skeletons of animals, yet such is indeed the case. They appear to have much more affinity to the vegetable, than to the animal, kingdom, like the loofah, or vegetable sponge, which is the fibrous skeleton of a gourd, prepared by removing the seeds and pulp and then cleaning up the network of fibres which remains.

That there is ample justification for this point of view is shown by the fact that it is only just over a hundred years since sponges were definitely proved to be animals. The earlier naturalists had all seen that they looked like plants, grew fastened to the sea bottom just like plants, and showed none of the obvious characteristics of animals. But in 1820 a British Zoologist named Grant took the trouble to examine sponges a little more carefully, and discovered that they possessed the most fundamental of animal properties; instead of obtaining nourishment by the chemical action of green colouring matter on the gases and salts in solution

in the sea, as do all the sea weeds, they feed on the minute animals and solid particles which float about in the water. These tiny pieces of food are taken into the tissues of the sponge and there digested, a process of which no plant is capable, and which stamps the sponges once and for all as members of the animal kingdom.

Since the time of Grant much work has been done on sponges; his results have been absolutely confirmed, and the place of the sponges in the classification of animals has been determined. So dissimilar are they in many particulars to the great mass of other animals, that they are generally considered an offshoot from the main line of evolution, with no relationships to any but the very simple protozoans, or single-celled animals, from which they originally sprang.

A sponge is best described as a sieve; all over the body are innumerable minute openings, while here and there are larger openings which can be seen by the naked eye and are called oscula. Within the body there are a complicated series of fine canals, at some point of which are special chambers lined with tissues which bear delicate, whip-like hairs which are perpetually beating, and are so

arranged that they produce a current of water which flows in through the minute openings all over the surface and passes out by way of the large oscula. As the water passes through the body of the sponge in a steady, uninterrupted stream, the tiny food particles in it are seized by the tissues and digested in the manner described by Grant.

There are very many kinds of sponges which are classified according to the kind of skeleton they possess, the great majority have a framework of very beautiful little spicules of many shapes, some like needles, others with three or four arms meeting in a common centre, others in the form of anchors, or hooks, or spiney balls; others again may be very long as in the beautiful glass-rope sponge found in deep water and frequently exhibited at museums. These spicules may be formed of carbonate of lime, but in the majority of cases are composed of silica.

Clearly such sponges would be useless for commercial purposes, we should remove the skin as well as the dirt if we attempted to wash ourselves with them. The sponge of commerce belongs to a third group the skeleton of which is composed of a horn-like substance known as spongin, which is rather

fibrous in appearance. Finally there is a fourth group of sponges which have no skeleton at all.

The greatest of the sponge fisheries is in the eastern end of the Mediterranean, the history of which goes back to classic times, for there are references to it even in Greek mythology, Glaucus, who built the Argo used by Jason, and who used to visit Oceanus on the bed of the ocean having been a sponge diver. There was a flourishing sponge fishery at the time of Aristotle of which this great father of science tells us. The Romans used sponges, particularly in the army, both instead of cups for drinking and as pads beneath the armour which protected their knees.

The Mediterranean sponge fishery remained the sole source of the world's supply until so recently as 1841 when, by one of those curious chances which are so often the starting point of new economic developments, a French sponge merchant was wrecked on the Bahamas in the West Indies. He at once noticed the presence of commercial sponges, collected as many as he could and sent them to Paris, where they found a ready sale. Since that date the sponge fishery in the Bahamas has developed steadily,

sponges to the value of over a million pounds being now annually exported, while the industry has extended to the coasts of Florida and to Cuba.

In shallow water sponges can be collected by fishermen, who wade about and pull them off by their feet or with knives, but the greatest fishery is in deep water, and is conducted by divers. The old method of naked divers, who descend holding a stone attached to a rope, is still largely employed in the Mediterranean, and expert divers can remain below water for up to four minutes, being quickly pulled as soon as they pull on the line. They then rest for about half an hour, before going down again. Some are said to be able to work at depths of one hundred feet. The modern method, introduced into the Mediterranean about the middle of the last century, is the employment of divers wearing suits or "scaphanders". Sponges are also collected by means of specially constructed dredges, which scrape along the sea-bottom.

All the living tissue has to be removed from the sponge before it is ready for the market. This was originally done by allowing this to rot away, but nowadays the sponges are

killed by treading on them. After which they are washed in water and then dried in the sun. In this state they are sold to dealers, who trim them up, finish the cleaning process, and then sell them, after grading them according to size and quality. The most valuable Mediterranean sponges are the beautifully soft Turkey solid and Turkey cup, and the honeycomb or bath sponge, while in America the sheepswool sponge is the principal product of the fisheries.

11. *Strange Food from the Sea*

At the mention of food from the sea the first thing we think of, inevitably, is the fish which follows the soup, or else the oysters which precede it, or perhaps the joys of lobster mayonaise, while, if our minds linger over the matter, crabs, shrimps, scallops, winkles, and various other kinds of shell-fish may be called to mind. But, though the true fish and the molluscan and crustacean shell-fish do provide the great mass of the edible products of the sea, innumerable kinds being eaten in different parts of the world, yet there are peoples, with more originality or less fastidiousness than ourselves, who

have been less conservative in their ideas as to the number and variety of the edible products of the sea.

Foremost in our list of these strange articles of food must be placed the bêche-de-mer or trepang, so popular in China. These animals are close relatives of our sea-cucumbers, sluggish, animated sausages which belong to the same division of the animal kingdom as the star-fish and sea-urchins. So great is the Chinese demand for them that, even so far away as the Great Barrier Reef of Australia, there is a flourishing fishery almost all the products of which are exported to the Chinese markets. Although the largest variety of any commercial importance, known as the "prickly-fish" or "prickly-red", is often over four feet long and more than four inches across; the commonest kinds are usually some eighteen inches long when fully extended, but can contract themselves to about half this length with a corresponding increase in their girth. They are of many colours, red, yellow and black being the commonest.

Nothing is easier than the fishery. The fishermen cross to the reef when it is exposed at low tide and collect the defenceless,

sluggish beasts till the tide returns. The catch is stored in sacks and, at the first opportunity, boiled in large iron cauldrons for about twenty minutes, after which the animals are slit open, gutted and then exposed to the sun until the greater part of the moisture has evaporated. The next procedure is to transfer the dried skins to a smoke house, usually of corrugated iron with layers of wire netting, on which to arrange the catch, in the upper half. The smoking process usually takes twenty-four hours, at the end of which the bêche-de-mer have usually shrunk to about a third their original size and, in the opinion of a witness, look " like charred sausages ".

All that now remains to be done is to pack them up and despatch them to the Chinese markets. The great point is that they must be thoroughly dry—must " rattle like walnuts in their bags ", to use a trade expression—for if there is any moisture left in them they will quickly become gelatinous and turn bad. The various varieties vary greatly in value—many cannot be cured at all owing to their soft texture—the best quality of all, known to the Australians as the black Teat-fish, and to the Chinese as

Se-Ok-Sum, being worth, before the war, about £150 a ton, while the poorer kinds have not more than a fifth the value. Although the great bulk is exported, a certain amount is used in Australia, where it is made into bêche-de-mer soup.

Both the Chinese and Japanese with their strange taste—as it seems to us—in dishes, eat jelly-fish. Two kinds are particularly used, the fresh animals being preserved in a mixture of salt and alum, or else laid between steamed oak leaves, being soaked in water, cut up and flavoured before being eaten.

Octopus, squid and their allies are eaten in very many parts of the world, not only by the natives of tropic seas but also in the Mediterranean. Any visitor to Naples who has wandered about the side streets will have seen the great piles of such animals exposed for sale in all the fishmongers' shops, while those who have lived on the usual Neapolitan food will have tasted the tough, and rather tasteless flesh which is usually fried. Fishing takes place largely at night, the animals being detected by the aid of a powerful light which is fastened to the prow of the boat and which also helps to attract them. Another strange animal eaten

in the Mediterranean is the sea-urchin, which is collected from shallow water by means of a long bamboo, split into three at the end, which is used with great skill by the fishermen, who search for them around rocky coasts.

Although barnacles are, strictly speaking, crustacean shell-fish, we seldom think of them as edible, nevertheless they are occasionally eaten, one large variety, about nine inches long and three inches broad, found on the coast of Chili, being, according to Darwin, "universally esteemed as a delicious article of food", another being eaten on the coasts of British Columbia, while a stalked barnacle is eaten by the fishing population of Brittany and parts of Spain.

Sea-weeds are eaten, or used in the preparation of food materials, in almost all parts of the world. The common red, rather iridescent Carrageen Moss of our own coasts is eaten in Ireland and is also used in the preparation of jellies and, incidentally, as a thickening for textiles and as a vegetable glue. Another red weed, Dulse, can be cooked and eaten as a vegetable, though in some parts it is dried in the sun, rolled and then chewed like tobacco, while another variety known as Pepper-dulse is sometimes

used as a condiment in Scotland on account of its peppery flavour. Yet a third weed, called Laver in this country and Sloke in Ireland, is eaten either cooked or pickled in many parts, and both this and Dulse are regularly sold in the coastal villages of south western England, and the latter in the fish market at Aberdeen. Sea weeds are also largely eaten in Japan, where they are also the raw material for the preparation of agar-agar, a jelly used as a culture medium in the study of bacteriology. All these are red weeds, the brown weeds, though valuable as manure and as the source of potash and iodine, are never used for food.

12. *The Shipworm and Other Marine Borers*

Since the days of the ancient Greeks and Romans the shipworm, the "calamitas naviuni" of Linnæus, has been known and feared on account of the great destruction it causes to all timber in sea-water, and particularly to wooden ships and harbour works. Greek triremes, Venetian galleys, and Drake's famous ship "The Golden Hind" all were rotted away by the boring of these creatures, while in 1730, by eating into the

dykes of Holland, they threatened the very existence of that country. Even to-day, although steel ships have nothing to fear from them, they cause extensive damage to wooden piers and wharves. Destruction estimated at ten million dollars was done in San Francisco Bay as the result of the great spread of Teredo in that region between 1914 and 1920.

In spite of its common name, Teredo is no worm, but is a bivalve mollusc, though this was not recognized until 1733 as a result of the work of a Dutch investigator appointed to inquire into the cause of the damage which had been done to the dykes. But, though it agrees in all essential structures with such typical bivalves as the mussel or the oyster, it is so specialized on account of its peculiar method of life that at first sight it seems to bear no resemblance to them, while its elongate form immediately suggests that of a worm.

The shell valves, instead of covering the entire animal as in a typical bivalve, are very small and confined to the extreme front end of the animal. Between, and slightly on the under side of them, lies a round sucker known as the foot, while immediately above that is situated the mouth.

At the other end of the elongated unprotected body there are a pair of short tubes, the siphons, and at their base two calcareous paddle-like plates known as the pallets. During life the siphons project into the sea through the opening of the burrow in which the animal lies, and a constant stream of water passes through one of them into an open passage, the inhalent gill-chamber, which extends almost the entire length of the animal. This is separated from a second, or exhalent, gill-chamber, by a finely perforated partition, the gill, which is covered with delicate constantly-moving hairs or cilia which are responsible for the flow of water through the gill chambers. The water passes through the tiny interstices in the gill, leaving behind it any suspended particles which are carried to the mouth, and enters the second chamber in which it flows backward and is expelled through the second, exhalent, siphon. If the siphons are touched, however lightly, they are immediately drawn back behind the pallets which are pushed forward so as to close the opening of the burrow. This opening is very small—not much bigger than a pin-head—but within the burrow widens out until it may be half an inch or more across.

It is lined everywhere except at the inner end by a smooth calcareous substance which is laid on by the animal. The inner end of the burrow only remains uncoated so long as the animal continues growing and actively boring ; as soon as it ceases burrowing, either on account of age or lack of further wood to bore into, this end also is coated over, and a limy tube is formed which entirely surrounds the animal except for the opening at the hind end.

For a long time naturalists were very divided in their opinions as to how Teredo bored into wood—saying that it did so by the suction of the foot ; by the rhythmical passage of the water in and out of the body ; by the help of some substance which dissolved away the wood ; or by the mechanical boring of the shell valves. This last explanation has found most support, and quite recently an American scientist, Dr R. C. Miller, has published a paper which seems to settle the matter once and for all. In order to understand the beautiful mechanism employed it is necessary first to describe the structure of the shell. The valves are very irregular in outline, but they can be divided into three portions, a posterior lobe consisting of a

broad wing often known as the auricle, a median lobe which forms the mass of the shell and is curved so as to form a semicircle, and an anterior lobe which only extends for less than half the width of the median lobe and is then cut away at right angles. The outer surfaces of these last two regions are covered with a series of sharply-pointed ridges, those on the median lobe passing diagonally across the anterior third of its surface, while those on the anterior lobe run parallel to the sharply cut lower margin. These latter ridges are continually being added to during the life of the animal. On the inside of the median lobes are two knobs, one above and one below, which are known as the dorsal and ventral articulations respectively, while extending down from the former of these is a long process, the apophysis, which gives attachment to the muscles of the foot. Now imagine the two valves placed one against the other. They will be attached by the two pairs of knobs and will be able to rock backward and forward upon these two points so that the edges of the valves will describe an arc of between twenty and thirty degrees. It is by means of this rocking movement, as we shall see, that the animal

is able to bore. Two muscles are attached to the shell and are responsible for the working of the boring apparatus—a very large posterior adductor muscle attached to the inner sides of the auricles and a much smaller anterior adductor attached to the inner surfaces of the anterior lobes.

The wood at the lower side of the head of the burrow is gripped by the foot which acts as a sucker, while at the same time a flap of skin which overlaps the shell valves grips it above. The shell is thus pressed firmly against the wood and is ready to begin boring. To do this the powerful posterior muscle is contracted, drawing the anterior lobes apart so that the sharp ridges with which they are covered scrape off the surface of the wood at the end of the burrow, while at the same time the ridges on the median lobes widen the opening behind. The small anterior muscle now comes into play and by contracting draws the anterior lobes together again—a much easier operation since the surface of the wood offers no resistance to movement in this direction. The foot then loosens its hold and moves a very slight distance laterally, when the same operation is repeated. This goes on over and over

again until the shell and front half of the body have been twisted completely round from their original position, when the movement is reversed. As a result of this continual turning of the shell the inside of the burrow becomes perfectly smooth and circular. The whole mechanism of boring is a model of efficiency, and yet it is an adaptation of the purely protective shell possessed by the typical bivalve.

The fragments of wood scraped off are swallowed and make their way through the body before being ejected by way of the exhalent siphon. It has long been a matter of dispute whether Teredo can actually digest the wood or whether it passes through the body unchanged, but recent investigations seem to point to the animal being able to feed to some extent upon the wood into which it bores. There is a large extension of the stomach which is always filled with wood shavings and is obviously well adapted for the storage of a slowly digested diet such as wood, and we have some evidence that ferments are produced which can convert wood into sugars which can be absorbed.

It is easy to see that once incased in his burrow no shipworm can ever leave it, and

if animals are dissected out of the wood they are quite unable to form new burrows. How then does infection spread with such alarming rapidity? During the summer months the sexual products, eggs and sperms, are discharged in immense numbers through the exhalent siphon into the sea where the eggs are fertilized and the young organisms begin to develop. In a few species, such as the common *Teredo navalis*, the eggs remain in the gill-chamber and early development takes place there. Development proceeds on exactly the same lines as in any other bivalve, and after a few days a little " larva " is formed possessing two shell valves which entirely enclose the body. These larvæ swim freely by means of a circle of cilia which they can project between the valves. It is not known for how long they remain in this state, but they can probably do so for several weeks, during which time they may be carried by ocean currents or other agencies for great distances. This is the only period during its life when the shipworm possesses the power of locomotion, and it is then that it is able to spread by infecting fresh timber. Wood appears to exercise some kind of chemical attraction for the larvæ, which will

remain on its surface once they happen to drift there, whereas they will not remain on stone or any other hard surface. An extract of wood made with ether or alcohol has the same attraction for them.

After they settle on the wood the larvæ begin to change. They lose the ring of cilia but are able to crawl about for some time by the aid of a long tongue-shaped foot which they develop at this stage. Having found a good place, they finally begin to bore, first protecting themselves, it is said, with a covering of wood and other particles. Both shell and foot are quickly converted into those of an adult Teredo, while the body grows more and more elongated as the burrow becomes longer. Usually they enter the wood at right angles to the grain, but they soon turn in the direction which it runs. However full a piece of timber may be with Teredo, the burrows never run into one another, rather than do that they will turn and twist and interlace with one another in the most complicated manner, as an X-ray photograph of a heavily infected piece of timber shows very clearly. A stout piece of timber may be so completely eaten away that it can be crushed between finger and thumb.

From a scientific point of view the most interesting feature about the shipworm is the remarkably efficient way it is adapted to its strange mode of life. Originally, as the structure of the larva tells us, like any other bivalve it has in the course of ages evolved the elongate body of a boring animal and a shell which has lost its original protective function, developed a second, ventral, articulation, a characteristic shape and a series of sharp ridges, and so become a boring tool. This is worked by means of a pair of muscles, one of which is some thirty times the size of the other—although in the bivalves generally they are about the same size and serve to close the shell. It possesses a foot which acts as a sucker, a pair of pallets (not developed in any other molluscs) for the protection of the opening of the burrow, a modified digestive system for dealing with the wood taken in, and probably especial digestive ferments. There is no better example in the whole of the animal kingdom of that adaptation to circumstances which is so marked a character of life.

Six-foot Worms

There are many species of shipworms, some of which may attain a length of from five to six feet with burrows as much as an inch wide, but the English species are never more than eighteen inches long. The rate of growth is very rapid, so that immense damage can be caused in a very short time. All kinds of timber are attacked, though some, such as greenheart, jarrah, and turpentine, resist longer than others.

Other enemies of wood whose ravages are more apparent, slower but as destructive in the long run, are small shrimp-like crustaceans, seldom more than a third of an inch long, of which the gribble, *Limnoria lignorum*, is the best known and the most widely distributed. They attack the surface layers of the wood—unlike Teredo which can bore to great depths—eating it away with their powerful and specialized mandibles. They usually bore in the direction of the grain in the soft wood between the annual rings of hard wood; the burrows run just beneath the surface, and their course can be traced by the presence of a row of fine openings through

which the animals take in the water necessary for respiration. Unlike the shipworm, the gribble has only a very few eggs, but these are carried by the parent until the young have developed to about one-fifth the size of the adult and so are able, immediately after hatching, to shift for themselves, which they do by hollowing out burrows from the sides of the parent burrow. Only the full-grown gribble, apparently, migrates to fresh timber. As a result of their activities, the surface of the wood soon becomes rotten and drops away, and the animals then eat their way in further and so gradually the wood is destroyed. Moreover, they often prepare the way for the attacks of Teredo, the larvæ of which find in the excavations of the gribble shelter wherein they can begin boring.

The stone borers, of less economic significance since their excavations are, of necessity, so much slower, are principally molluscs. The piddock, a fairly near relative of the shipworm, is the chief agent of destruction. It resembles a typical bivalve in that the shell completely covers the body; but this is adapted, like that of Teredo, for boring, which is accomplished in a somewhat similar manner by a rocking to and fro of the shell

valves which bear a series of hardened teeth which slowly grind away the rock. The burrows are much shorter than those of the shipworm since the piddock, though stouter, is never more than six inches long and has to maintain contact with the water so as to obtain food and oxygen. There are a number of other molluscs which bore in much the same manner, but in the Mediterranean is found quite a different type of stone borer. This is the date mussel, so called because of its resemblance in shape and colour to a date, which is a true mussel and bores only into limestone, which it dissolves away by an acid secretion—by chemical instead of mechanical action—the shell being protected from the action of the acid by a covering of brown cuticle. There are also a variety of smaller animals which bore into stone, notably several species of worms which construct little U-shaped tubes, so that both ends of the animal are in the sea but the body is fully protected; and a sponge which eats its way into stone in a very mysterious manner, and is of some economic importance because of its fondness for attacking the shells of oysters.

The problem of the protection of timber

against the wood borers is a difficult one. Sheathing with copper, a metal very poisonous to all animals, is perfectly efficacious so long as the sheathing remains intact, but it is very expensive. Many substances have been found which are poisonous to the shipworm and the gribble, but they are speedily washed out of the wood when exposed in the sea. So far the best results have been obtained by impregnating wood with creosote containing poisons in solution. The creosote is not readily washed out, and, though animals will eventually attack creosoted wood, they will not do so, or at any rate, far less speedily, if the creosote contains poison. Teredo has proved the easier animal to deal with, since there is a weak spot in its life history—the unprotected free swimming larval stage—when it is particularly susceptible to poisons and can be most easily subjected to them. But there is no such weak link in the life of the gribble, which is hatched out at an advanced stage in development and then remains in the parent burrow; the adult gribble is a resistant beast, and apparently able to swallow creosoted or poisoned wood with far less ill-effect than can Teredo—probably a reflection of the different modes

of digestion in the two animals. Protection from the shipworm can never be achieved properly until the gribble also is conquered, since the latter is its precursor, reducing protected wood to a state suitable for the incursions of the shipworm. The extensive series of experiments now being conducted in various parts of the world give us hope that eventually some poison and method of impregnation will be discovered which will succeed in checking the inroads of what, in the warmer seas in particular, are most disastrous pests. So much at least can be said for poison gas, that it has furnished, to date, the most efficacious poisons for the impregnation of wood against the attacks of marine wood borers.

Other Marine Topics

13. *Dredging in the Trondhjem Fjord*

The study of marine beasts leads the student far afield in quest of material to complete or extend his researches. Though the British seas possess a large and varied fauna, yet

both in the warmer waters of the Mediterranean and in the colder northern seas are to be found species of which we have few or no representatives. The fjords of Norway are of the greatest interest to the marine biologist for two reasons: he finds in them representatives of a definite arctic fauna unlike the boreal fauna of the British Isles, while beneath the extremely deep water of the fjords, which may descend to five hundred fathoms, is found a bottom fauna typical of the continental slope and quite unlike that found on the bed of the shallow continental shelf which surrounds these islands.

The Trondhjem Fjord, one of the largest in Norway, has a particularly interesting fauna, consisting as it does of a mixture of arctic and boreal, or north temperate, species. Moreover, though not the deepest of the fjords, the greatest depths probably not exceeding three hundred fathoms, yet the bottom fauna of the deep seas beyond the continental shelf is here well represented. Finally, there are ideal facilities for scientific investigation provided at the Biologiska Station on the shores of the fjord some two miles to the west of the town of Trondhjem. In the winter months the staff at the station

are engaged on the rearing of plaice in the large fish hatchery, but during the summer, owing to the kindness of the director, Dr. O. Nordgaard, scientists of all nationalities are free to work in the laboratory and to carry out investigations on the fauna of the fjord.

Dredging at depths of three hundred fathoms is no light matter and needs strong equipment and powerful machinery. Both of these are provided on the *Gunnerus*, the motor ship owned by the station, and especially built six years ago for this particular work. It is doubtful whether there is anywhere in the world, for her size, a better-equipped boat for this type of marine research. The dredge is attached to a wire cable about one inch thick and one thousand metres long, which is wound round a great steel winch amidships. This cable is carried forward, round an iron capstan and then back and over the side of the boat, being guided clear of the woodwork by an ingenious system of small steel rollers, two vertical and one horizontal. As the cable is payed out the capstan is revolved and the length of cable which passes is automatically recorded in tens, hundreds and thousands of

metres on three dial indicators above it. It is necessary to have some check of this nature, as it is impossible to feel when the dredge has touched the bottom by the feel of the cable as can be done when dredging in shallow water; instead the depth of the water is determined from the chart, and the cable is payed out until the indicator records a length of cable slightly greater than the depth: the winch is then stopped and dredging begins.

The dredge is dragged very slowly over the bottom for a suitable time, a quarter to half an hour usually, when the boat is stopped and the cable hauled in round the winch which is driven by the full force of the engine. It is a slow process winding in several hundred fathoms of cable, and seems doubly so as one waits impatiently to see if the particular beasts one has travelled so far to obtain have been taken in this haul of the dredge. Finally, however, the dredge arrives at the surface of the water, a triangular steel frame which bites into the sea bottom and to which is attached a long network bag, which usually comes up full of stones and of mud which oozes out through the open meshes of the bag. With the aid of a derrick attached

to the mast, the dredge is brought on board and then inverted over a large wooden box, into which fall the contents and over which the dredge is washed clean by hosing it down with sea water.

Next comes the sorting of the catch. A few of the larger specimens have already been picked out of the dredge, but the smaller ones are lost among the soft mud, and this is now shovelled on to sieves which are carried on a bracket attached to the outer side of the boat. The hose is then turned on again, and the mud is washed through the fine openings in the wire sieve, the stones and animals alone remaining. It is an easy matter to sort these by hand, rejecting the stones and other rubbish and putting the animals into pickling fluids or into sea water, according to whether it is necessary to preserve them for future examination or keep them alive for immediate observation or experimentation in the laboratory at the station.

Many of the animals taken are of great interest or beauty. Although those which are of the greatest interest to the zoologist are often insignificant in size, of no particular beauty, and of little interest to the

layman, yet there are many which both scientist and layman may admire. Of such are the corals which are very abundant on rocky bottoms, particularly *Lophohelia*, which forms great branching colonies bearing delicate polyps like orange flowers on a yellow bush; the sea pens, creatures allied to the corals and sea anemones, thin, delicate and feathery like a quill pen, coloured red, brown or yellow and varying in length between a few inches and a yard. Each consists of many individuals like a coral, but instead of a lime skeleton they are supported down the centre by a fine shaft which looks exactly like a thin straw. Many of them are highly phosphorescent and shine brightly in the dark.

There are many fine shell-fish—for example, the bivalve *Lima excavata*, a typical member of the deep sea fauna only living below one hundred and fifty fathoms, which is often six inches long and four or five wide, and has bright orange flesh that is considered a great delicacy by the fishermen. The lamp shells, representatives of the ancient but dying order of Brachiopods, although they are rare in British waters, are here numerous and in some cases large. The Trondhjem Fjord is particularly rich in

Echinoderms, the group which includes the star-fish and sea-urchin, amongst the most striking of which is undoubtedly *Gorgonocephalus caput-medusæ*, a large brittle star with long arms which divide and subdivide repeatedly to form a writhing mass of tentacles like the hair of the medusa after which it was named by the great Linnæus. There are large sea cucumbers, sluggish beasts like animated red or brown sausages; stalked crinoids or "sea lilies", absent from the British fauna, are occasionally to be found, also deep-sea sponges with especial root-like extensions for anchoring them in the mud, and others which grow on the rock —great white rounded masses often many feet across and of strange shapes like the whitened bones of some prehistoric monster— and many other rare and interesting beasts too numerous to describe. At the end of the day's dredging, the catch is taken back to the laboratory, the living animals placed in circulating sea-water until they can be examined and the preserved specimens put into bottles and labelled.

It is impossible to conclude even so brief an account of marine life and research in the Trondhjem Fjord without paying tribute

to the unbounded hospitality of Dr Nordgaard and his assistants at the Biologiska Station, and to the great part which has been played, and continues to be played, by Norway, a country weak in population and resources, in the study of marine biology and the other branches of the growing science of oceanography.

14. *Fish Out of Water*

Fish are so entirely associated in our minds with watery surroundings, either seas, lakes or rivers, that the very thought of fish on dry land appears fantastic and ludicrous. An eloquent witness to this is supplied by the common expression, "a fish out of water". But, nevertheless, there are exceptions here as to so many other apparently hard and fast rules, and, as usual, the exceptions are of an interest befitting their rarity.

In this country there are no fish which live habitually out of water, though several are able to do so on occasion. Some of the little shore blennies which are left behind by the tide in rock pools frequently find themselves stranded when the tide goes out,

but they always manage to survive till the water returns, and may even crawl about on rocks, like lizards, using their fins as legs. The common eels can live for long periods out of water, and move across country from one stream to another and even climb slippery posts. All this they do by squirming movements of the body, not using their fins in any way. They can escape from tanks either by working their way out head first, or, if that is impossible, by turning round and throwing their tails over the edge and so gaining a hold which enables them to jerk their bodies over. While wandering over fields they frequently eat vegetable food —though their normal food is fresh water animals—and they appear to have a special preference for green peas! Pike are also known to wander overland.

But we must turn to tropical fishes for the most striking examples of walking fishes. Of these two stand out pre-eminent, the Mud-springing Gobies and the Climbing Perch.

The Walking Goby is one of the quaintest of fish, it has a relatively big, rather flattened, head from the top of which project the large eyes, and has a comically serious expression. Its eyes are exceptional, not only in their

size, but also in their power, owing to their elevation above the head, of working together like our own, but unlike those of the majority of fish, which are situated on either side of the massive head. Moreover, they are able to turn in all directions, and are probably of the greatest use to the fish in its journeyings on land.

The Gobies live on the shore between tide marks or else in marshes or mangrove swamps, from which they frequently make excursions on land of many hours' duration. The front pair of fins are used as legs in walking, while the hinder pair are converted into a kind of sucker by means of which they hold on to rocks, or even to the branches of trees, for they are able, by means of these fins, and by twisting the body, to climb on to the lower branches of trees. When disturbed they will drop off the branches into the water or mud beneath. They are also said to " skip through the grass " and to be very quick in all their movements.

Naturally their greatest problem when out of water is the obtaining of the oxygen necessary for respiration. An aquatic animal obtains this from the water by the aid of gills; a terrestrial animal from the air by

means of some kind of lung; but what is to happen to a fish which forsakes water for the land? It must clearly develop some new means of obtaining the life-giving oxygen. In the case of the Goby the cavity which contains the gills is exceptionally large, the extra space being filled, not with the gills, but with *air*, so that the original gill chamber has become a kind of lung. The Gobies also appear to have the remarkable power of breathing through their tails; for they are said to sit on land with only the tips of their tails in water, through the skin of which oxygen is taken into the blood from the water.

The Climbing Perch is famous on account of its habit of mounting palm-trees, and for the length of time, as great or even greater than in the case of the Gobies, it can live out of water. Its fins and the covers of its gills are fitted with spines, which enable it to grip the bark of the tree as it works itself upward. Specimens kept in captivity are reported to have leapt repeatedly out of a tank which had walls two feet high.

This fish has gone even further than the walking Gobies in the development of a lung. Not only is the gill cavity greatly

extended upwards on either side of the head, but the delicate skin which lines this extension is intricately folded so that the whole structure has become known as the "labyrinthine organ". It is undoubtedly an organ for breathing air, a lung, and the extra supply of pure blood laden with oxygen which this supplies to the brain of the fish is quite possibly the reason for its exceptional intelligence amongst fish, for the greater the amount of oxygen present the more work the brain will be capable of.

Other fish which make frequent excursions on land are the Carplings of Mexico and Central America, which are said to "hop about on land like fleas". They have no spines to enable them to hold on to hard surfaces, but seem to manage quite well without them, holding on with their tails instead. Like the Climbing Perch they are among the most intelligent of fish and, when kept in captivity, will leap out of water in their eagerness for food when they see their owner approaching.

Perhaps the most amazing fact of all, and one which shows how far these fish have gone in the change from an aquatic to a terrestrial existence, is that if the Walking Gobies are

kept under water for long periods, and so prevented from taking in air, they are drowned. Surely the strangest of deaths for animals which we normally consider as entirely dependent upon water as we are upon air.

II. Heredity

15. *Heredity and Environment*

As a result of his breeding experiments the Abbot Mendel in 1865 gave to the world three conceptions which represent the foundation of the great modern science of Heredity. Unlike his predecessors he studied not the whole animal or plant but only certain definitely contrasted characters, such as round and wrinkled seed or long and short stem in the pea. By crossing individuals which possessed these contrasted characters, he found that these were inherited according to definite rules and quite independently of the other characters which go to make up the individual; and this led him to the conception of "unit characters", since they

behaved like units in inheritance. He discovered, moreover, that, though the hybrid individual was in its nature mixed—not "pure"—yet the sex cells or gametes (eggs and sperms as the case may be) were invariably pure, there being a segregation in the gametes, each possessing a single complete set of the factors which are responsible for the production of the characters. Finally, the zygote—the fertilized egg: the starting point of the new individual being formed by the union of egg and sperm contained two sets of factors, the one from the male parent and the other from the female parent, and, though these might be identical, in which case the individual would be pure in every respect, or dissimilar with regard to one or more factors, in which case the owner would be hybrid for the characters for which they were responsible; yet in either case the zygote had a double structure.

Mendel's laws were purely empirical, he knew of no mechanism within the body which could account for the results of his experiments. This mechanism was not discovered until later, when the nature and behaviour of the nucleus which is present in every cell came to be investigated. Within

the nucleus lie a number (fixed for the species, but very variable for different species) of darkly staining rods which have become known as chromosomes. Although not apparent during the resting stage of the cell, they invariably appear, and in exactly the same form, whenever the cell divides. Each chromosome is paired, so that there are two complete sets, and, since they divide with the utmost exactness at every division of the cell, they retain their identity throughout all the cells in the body. Before the formation of the gametes, however, there is always a "reduction" division in the course of which the chromosomes, instead of each dividing, come together in pairs, like to like, and are then separated into two halves, each consisting of a complete single set of chromosomes. The fertilization of the egg by the sperm is accomplished by a fusing of the two nuclei, so that the new compound nucleus consists, as in the parents, of a double set of chromosomes. It is widely accepted at present that on the chromosomes lie the factors which are responsible for the appearance of the characters of the individual, while in the reduction division is recognized the mechanism which ensures the segregation

of the factors in the gametes, since only *one* factor for each character can pass into each gamete; finally, the fusing of the male and female gametes results in the double nature of the zygote and the adult organism into which it develops.

It was inevitable, since the early development of Heredity was in the hands of zoologists who were almost exclusively morphologists—students of structure, not function—that great emphasis should have been laid at first upon the structure of the chromosomes. The factors were visualized as a row of discrete dots which together made up the chromosomes. This attitude—though a perfectly natural stage in the development of a new science—had, and continues to have, unfortunate results on general biological thought, since it led to a dogmatic attitude with regard to Heredity. It was held that the constitution of the adult individual was absolutely settled once and for all by the nature of the factors which were borne on its chromosomes. Environment, therefore, could have no effect; if the stock was "bad", improved conditions or, in the case of mankind, better education were useless, and might even be definitely harmful.

One of the great modern developments in biology has been the recognition of the great importance of environment. This has been revealed by research in many and most diverse fields. Work on tissue culture has shown that the development of the different tissues of the body is not determined by something within the cells, but by the environment in which the cells find themselves. The unspecialized cells of the embryo become differentiated according to where they lie in relation to other parts of the developing organism. Pieces of the skin or kidney lose their specialized structure when cultivated in media outside the body, and become undifferentiated cells such as are found in the embryo; but if pieces of the connective tissue which lie in contact with the skin or kidney are added to the cultures, the cells begin to redifferentiate and become once more specialized skin or kidney cells. Again, sex is determined by the factorial content of the individual and so, according to the old view, it ought to be unchangeable; yet there are many instances of the sex of an animal being dependent upon its environment. For example, the American slipper limpet, *Crepidula*, lives in chains, each mem-

ber being attached to the shell of the one beneath it; the eldest members of any chain are always female, the middle ones hermaphrodite, and the youngest male. If a young Crepidula settles on the end of a chain, it develops into a male, becoming later hermaphrodite and finally female; but if it settles on its own—the founder of a new chain—it develops immediately into a female. The sex assumed depends on the external environment, just as the development of the different tissues depends on the internal environment.

In Heredity also the importance of environment is at last becoming recognized, as Professor Jennings emphasizes in his admirably lucid essay "Prometheus",[1] which it is to be hoped will be widely read. Although the rest of Mendel's conclusions stand, his conception of unit characters can no longer be accepted. Every character is the product of not one but many factors—the absence of any one of which may result in the non-appearance of the character, a fact which accounts for Mendel's error. Each factor is now conceived of as a centre of chemical activity, not as a definite structure, and it

[1] *Prometheus*. By H. S. Jennings, Kegan Paul, 2/6.

is probably the interaction of the chemicals or "hormones" produced by the different factors which leads to the appearance of the various characters. The manner in which these substances react with one another, and therefore the nature of the characters to which they give rise, is dependent on the environment. The axolotl of the Mexican streams, a sluggish creature like a large newt with gills, a tail bearing a fin, and all the characters needed for an aquatic existence, may become, if conditions are suitably altered, a terrestrial animal without gills or fin and with a smaller and more easily managed body—the amblystoma. It may become mature and lay eggs in either condition, and the offspring, if the environment remains the same, develop like their parents.

The recognition of the influence of environment represents a great advance in biology, but its social implications are no less important. It is impossible to control the factorial content of even the lowliest animal except for some few factors, and it is quite out of the question for so highly organized and so slowly breeding a creature as Man. The best that can be hoped for from eugenics is the cutting out of such definitely harmful

characters as feeble-mindedness, which is known to be inherited. For the rest, the mating of brilliant parents, though it may produce on the average rather more intelligent children than the mating of stupid parents (and such difference as there is may be due largely to the difference in intellectual environment), is just as unlikely to give rise to children of exceptional brilliance. But it *is* possible to control environment and so to order social conditions that the highest qualities that lie latent in the constitution of any child shall be able freely to develop. We cannot alter the factors on the chromosomes, but we can influence them in their interactions so as to make them give the best results possible.

Herein lies the biological justification of all schemes of social amelioration, and the final answer to all those who advance the old argument that any improvement in social conditions, by abolishing the struggle for existence and so rendering natural selection inoperative, leads to an increase in the unfit, who would not have been able to survive under "natural" conditions. Natural selection does exist, and what is essential is that we should so arrange the conditions of life

that it will have the very best of material upon which to work, and so that it will act by picking out for survival those members of the race who are mentally and socially "fit", and not leave conditions such that life becomes a struggle in which the selfishly assertive and purely animal have the advantage—the superior "survival value"—over the finer types of mankind.

16. *The Determination of Sex*

The great majority of the species in the animal kingdom, from the simplest to the most highly evolved, comprise, either always or at certain periods only, individuals which are male and individuals which are female. Only a very few animals, usually degraded parasites or dwellers in some peculiar environment, are sexless. Undoubtedly the development of sex has been of vital importance in the evolution of life, and it is not surprising, therefore, that biologists have devoted much of their time and thought to the investigation of the nature and determination of sex.

What *is* the supreme advantage of sex which has outweighed its often manifest disadvantages? What mechanism is there

which determines that a certain proportion of individuals shall be male and a certain proportion female? Modern research has not yet revealed with certainty the answer to the first of these questions, although it is not improbable that the blending of the maternal and the paternal elements in the offspring, by affording an infinite number of different combinations, is essential for the production of that variation in succeeding generations upon which natural selection acts by picking out those which are most suitable for the continuation of the species. The answer to the second question, however, is now becoming clear, and in this article some account of recent work on this subject, and the conclusions which have been drawn from it, will be given.

The fundamental difference between a male and a female—although there may be many secondary differences—is that the former produces sexual products known as spermatozoa, which are very small and have the power of movement; while the latter produces sexual products in the form of eggs, which are larger, contain food for the developing embryo, and cannot move. In all but the simplest animals the entire body is made

up of a vast number of "cells" which, in the higher animals especially, become specialized for various kinds of work, some forming nerves, some bone, some muscle, and so on. All these cells which form the body are known collectively as "somatic" cells, while those which are responsible for the production of the sexual products are called "germ" cells. There is an absolute distinction between these two sets of cells, which become separated almost immediately after the fertilized egg begins to divide up into cells—a process which is continued until the adult size is attained. No germ cell can become a somatic cell—they can all be removed without affecting the rest of the body—and no somatic cell a germ cell.

It is characteristic of every cell that it possesses within itself a small round body known as a nucleus. This consists of a membrane inside which lies a tangle of tiny threads of a substance which, on account of its great affinity for stains, is called chromatin. Before the cell divides, this tangle of threads becomes sorted out, as it were, into a number of distinct and separate little threads called chromosomes. These are excessively minute and need for their ex-

amination the highest powers of the microscope. but, as a result of their very careful examination by many scientists, we know so much about them that it is possible to affirm with a considerable degree of certainty that they are the bearers of the hereditary "factors" which govern the constitution of any animal.

Every species of animal has a definite number of chromosomes; it may be only two or be several hundreds, but it *never* varies for that particular species. At each division of the cell the membrane round the nucleus breaks down and the chromosomes come to lie in a line across the middle of the cell, while at the same time from the extremities of the cell a series of most minute fibres appear, which radiate out and unite with one another across the middle of the cell so as to form a spindle. Each chromosome now divides longitudinally, and the halves pass to opposite ends of the spindle. The cell now divides and two new cells are formed, the chromosomes losing their definite shape and passing once more into their indefinite "resting stage". By means of this beautifully accurate mechanism, the number and individual identity of the chromosomes is maintained in every cell in the body.

Since a new individual is formed by the union of the egg and the sperm, it might appear that the offspring would in this way possess twice as many chromosomes as the parents. This, however, is not the case. During the development of the sex cells there is a particular division—characteristic of the germ cells *only*—known as the reduction division, in which the chromosomes, instead of splitting, come together in pairs and are separated into two sets, exactly half passing into each of the two new cells. These new cells develop directly into spermatozoa or eggs, as the case may be, and possess *invariably* half the number of chromosomes that are present in the other cells. When the egg and the sperm meet and unite a new nucleus is formed which has the full number of chromosomes, half of which have come from the male parent and half from the female parent.

It was discovered by the Abbot Mendel about 1865 that the inheritance of certain definite "characters", such as colour, size, etc., follows a definite course, and his work has been developed in recent years into the great science of Mendelism, or Heredity. It is impossible here to go into this complex

subject or to explain the nature ofthe evidence, but there are many reasons for thinking that the "factors" which determine the characters are borne on the chromosomes. Sex is a character, and the factor for it is borne on the chromosomes in the same way as the other factors. This was established by the discovery that certain characters were "linked" with sex in their inheritance. Thus, to quote one example out of many, all tortoiseshell cats (in the normal course of events) are female, the "factors" responsible for the tortoiseshell colour being borne on the *same* chromosomes which bear the factors for femaleness.

But is there any difference between the chromosomes of males and females which will support this theory? Exhaustive examinations of the chromosomes of many animals has revealed the fact that, although there are two pairs of all the other chromosomes, one member from the male parent and the other from the female, there can be distinguished in many animals, either in the male or in the female (*never in both*), either one *odd* chromosome or else a pair composed of *unlike* members.

In the fruit fly, *Drosophila*, the animal

which was used by Professor T. H. Morgan, of Columbia University, in his great researches on heredity, there are only four pairs of chromosomes, three of which, two large pairs and one small pair, being always the same in male or female, but the fourth consisting of members which are alike in the female, but *unlike* in the male. These are the sex chromosomes—or "X" and "Y" chromosomes, as they have become known to science—and in them we have a mechanism which can determine sex.

Since in the process of reduction division which precedes the formation of the eggs and sperms the pairs of chromosomes are parted, the eggs of *Drosophila* will all contain three ordinary and one "X" chromosome. The sperms, on the other hand, will be of *two* kinds, one with three ordinary chromosomes and one "X" chromosome, and the other with three ordinary chromosomes and a "Y" chromosome. Accordingly, half the eggs will be fertilized by one kind of sperm, and half by the other. Since the half which are fertilized by the sperms containing the "X" chromosome will all contain two "X" chromosomes, they will all develop into females, while the remaining eggs will

be fertilized by sperms containing the " Y " chromosome, so that they will all become males.

Here we have a very simple mechanism for regulating the approximately equal production of males and females in any species of animal. In some animals, such as the birds, it is the female which possesses the unlike pair of chromosomes (the " X " and the " Y ", or one " X " alone), and the male which has the like pair, consisting of two " X " chromosomes, and there are thus two kinds of eggs and one kind of sperm ; but the result is the same. The fertilized eggs are of two kinds, one of which will develop into males and the other into females.

It might be thought that, a mechanism for sex determination having been discovered, the whole question was finally settled. But that is far from being the case. We know of many instances where the sex of the individual depends upon certain external conditions and does not appear to have been predetermined. There is a certain worm-like creature found in the Mediterranean, and called *Bonellia*. The body consists of a roundish mass some two or three inches long, to which is attached a long and very

extensile proboscis. Now all these creatures are female, but if their kidney sacs are opened a number of minute semi-transparent animals are found living there parasitically, and these have been identified as the male *Bonellia*. All the very young *Bonellia* are alike, and whether they develop into males or females depends on whether they settle on the proboscis of a fully-grown female or settle down to a free existence on their own. If they alight on the proboscis of a female, they develop into males and creep into her kidney sacs, where they spend the rest of their lives, but if they remain free they become females.

Again, there is a limpet called *Crepidula*, which has been introduced into this country from America, and which lives in chains, one individual being attached to the shell of the individual beneath it. The oldest members of any chain are always females, the middle ones are hermaphrodite, and the youngest ones are male. Thus a young *Crepidula* which attaches itself to the end of a chain always becomes first a male, and then later on a female; but if it settles down by itself and so forms the beginning of a new chain, it develops directly into a

female without ever passing through the male state.

The simple mechanism which has been described, and which appears to determine definitely and finally the sex of every individual, does not seem to work in these cases; there is some other complicating influence. For some time these and similar cases seemed inexplicable and impossible to bring into line with the chromosome theory. Recently, however, Professor Goldschmidt of Berlin has evolved a theory which seems to bring most of the evidence into harmony. According to his view every animal has potentially the power of becoming male or female, those which are male possessing a definite excess of the "male producing substance" over "female-producing substance" in the sex chromosomes, the reverse being the case in the female. He has found evidence for this theory in a very interesting way.

There are many different races of the gipsy moth in the world, and Professor Goldschmidt found that by crossing members of these races in various ways all manner of intersexual moths were produced, from males with a slight tendency to femaleness to females with a slight tendency to maleness,

as well as normal males and females. To account for this, he considers some races to be "strong" and others to be "weak", the former having a much greater quantity of both male and female-producing substances than the latter. Accordingly, when a "strong" male is mated with a "weak" female, the male offspring will be purely male, but the female offspring, on account of the male-producing substance from the "strong" male being greater than the male-producing substance from the "weak" male which is their normal parent, will not possess the necessary excess of female-producing substance, and so will not be pure females, but females with certain male characters.

Professor Goldschmidt further considers that the sex-determining substance in the chromosomes consists of a ferment which produces sexual "hormones", which in turn are responsible for the development of the sexual form. Since there are both kinds of sex ferments in each animal, so there will be both types of sex hormone produced, only the action of the one which is in lesser quantity will normally be inhibited by the presence of the one in greater quantity. If, however, during the life of the animal it

comes under the influence of certain conditions which alter its rate of growth and usual internal co-ordination, the sex hormone which would normally be suppressed may be able to assert its influence and to decide the sex of the animal. In this way he accounts for the conditions found in *Bonellia* and in *Crepidula*. His theories, it may be remarked, are not so simple as here stated, although the attempt has been made to simplify them without distorting them.

Hitherto we have, in the main, been discussing insects, but if we turn to the vertebrates, and particularly to the mammals, in which man is included, we find a rather different state of affairs. In the insects the sex-producing substance in the sex chromosomes of every cell produces the hormones which decide the sex, but in the vertebrates these hormones are produced in definite "endocrine" organs, and *not* by each individual cell. These organs manufacture a substance which passes directly into the blood stream, for they are "ductless glands", like the thyroid, pituitary and adrenal bodies, of which so much has been heard in recent years. They are located in the tissue of the sex organs—in the testis in the male and the

ovary in the female—and the hormones they produce are responsible for the appearance of the "secondary sexual characters" which distinguish males and females externally.

The presence of the sex-producing substance in the chromosomes is necessary for the formation of either a testis or an ovary, but after that, in the vertebrates, its function ceases. All depends, then, upon the hormones produced in these organs. If they develop and function normally, then the individual becomes a normal male or a normal female, as the case may be, but if they are destroyed—by accident, operation, or disease—then the normal sex characters no longer appear; while if the sex organs of the opposite sex are grafted in place of those which have been lost the characteristics of the other sex begin to develop. Thus a castrated male guinea-pig into which ovaries are grafted develops as far as possible along the lines of a female, both in structure and instincts, while the reverse condition is found in castrated females into which testes have been transplanted. Similar experiments, with similar results, have been carried out on many different vertebrates, particularly among mammals and birds.

Finally we come to Man. Naturally we cannot experiment upon man as we can upon animals, so our knowledge is limited. There is, however, no reason for doubting that a similar state of affairs exists here as in the remainder of the mammals. We know of many cases of sex-linked inheritance in man, such as hæmophilia (a deficiency in the blood which renders it unable to coagulate, so that it is impossible to stop the flow of blood from a wound), colour blindness, night blindness, etc. Hæmophilia is only found in the male sex, and always skips a generation, being inherited only through the female, and not directly from a male parent.

It follows precisely the course of a factor which is carried on the same chromosome which carries the factor for sex.

A great deal of attention has been attracted in recent years by the experiments of Voronoff and Steinach. The former, after considerable experience on grafting in sheep and goats, turned his attention to human beings, and by grafting portions of the testes of chimpanzees—the animal most akin to man—has succeeded in supplying the necessary sex hormone when that has been absent as the result of disease, accident or age, so that

the individual has become to some degree "rejuvenated". Steinach, by operating and ligaturing the duct from the testis to the exterior—quite a simple matter—has succeeded in inducing the testis to manufacture an increased amount of the hormone, with a similar effect on the patient.

As in the other mammals, therefore, sex in man is determined by the chromosome constitution, and the later development of the sexual organization is controlled by the hormones from the sex glands. The knowledge that we may gain from the study of the determination of sex in animals—and there is yet much to be learnt—has, therefore, a very practical bearing on our knowledge of our own constitution. We may never be able to control the production of children of one sex or the other—it is perhaps not particularly desirable that we should, nature manages these affairs very well by herself—but we can hope in time to understand and so to cure, any sexual abnormalities and deficiencies, or premature senility due to lack of the necessary sex hormone, an addition of very first-rate importance to medicine and to human knowledge generally.

III. Biology in the Laboratory

17. *Tissue Culture*

In the year 1910 an American biologist, Dr Ross Harrison, succeeding where many had essayed and failed, made the fundamental experiments which laid the foundations of that very valuable branch of science known as tissue culture. For the first time pieces of living tissue, cut away from the parent body, were not only kept alive, but actually grew under these conditions. In other words the tissues were cultured under artificial conditions quite apart from the body of which they had originally been a constituent.

The particular tissue employed by Dr Ross Harrison in his famous experiments consisted of portions of the spinal cord of tadpoles. He placed minute fragments of the cord in clotted drops of lymph—a nutrient body fluid allied to the blood—which he took from the bodies of adult animals of the same species as the tadpoles. By dint of the greatest care in manipulation and experimentation, he succeeded in keeping these aseptic, *i.e.*, free from bacteria which would speedily have

converted them into putrient specks, and therein lay his greatest triumph. He next suspended his fragments of spinal tissue embedded in lymph, from the under surface of this sheet of glass, and studied them closely under the highest powers of the microscope. He then saw the cut ends of the nerve fibres grow outwards, in one case to the extent of over one millimetre in two days, and knew that he had succeeded.

Since that date not only has Dr Ross Harrison extended his work, but the study of tissue culture has made rapid strides as a result of the work of many other scientists, not only in the United States, but also in many of the European countries. As in the early days of all new avenues to knowledge, exaggerated claims were perhaps originally made as to the results to be expected from this work, and the doubts occasionally expressed as to its value are the natural reaction to this exaggerated optimism, but the increase in our knowledge due to the study of tissue culture is very real and very important.

The living body of any animal, however "simple", is the profoundest of mysteries, the body of a vertebrate, such as ourselves, composed of millions of microscopic "cells"

which have taken on many different functions, and so become aggregated into different tissues and organs, nerves, skeleton, spleen, kidney and so on, staggering to the imagination in its intricacy of detail, is almost impossible of belief as a *unity*. Physiologists have made great strides in their science of recent years, and almost every month sees us with some addition to our knowledge of the manner in which muscles work, or the digestion proceeds, but they tell us little of the most important—and most elusive—thing of all, how do all these organs and tissues work together in such complete harmony as to constitute an individual?

One result of the study of tissue culture has been to throw a thin beam of light, which further work may broaden, into the darkness of this mystery. For it has shown us that the tissues of the body are not independent of one another but that one depends on another, while, as was already known, all are bound together by a common dependence upon the chemical "hormones" produced by the ductless or "endocrine" glands, such as the thyroid, pituitary, etc. If the tissues are carefully isolated from one another then, in the absence of the controlling

substances formed by the other tissues, they lose their especial and characteristic form. The cells of the kidney, which form the tubules, whose function it is to purify the blood, when cultured outside the body together with fragments of the "connective tissue" —the supporting and packing tissue of the body—which normally surrounds them, live and do not change. But if all trace of the connective tissue be carefully removed a very remarkable thing happens; the very highly specialized kidney cells begin to lose their characteristic appearance, and gradually become like the cells of the early embryo before the different tissues have begun to develop. If a few connective tissue strands are now added to the culture exactly the opposite process takes place, the tubules reform from the mass of cells into which they have become converted.

The same thing has been shown for many other tissues, and a fact of the very greatest importance thus established. Without the presence of some, as yet mysterious, substance produced by the connective tissue cells, the cells which should form the kidney cannot do so, but revert to an earlier or "embryonic" state. In the early embryo, before the

tissues of the adult body have begun to form, all the cells are alike in appearance and also, probably, in their potentialities. They have in them the power of developing into any kind of tissue, and the particular fate which befalls any one of them appears to depend very largely on the particular position it occupies in the embryo. As the embryo develops, so do the different tissues gradually appear, and the cells from which they are formed have made their irrevocable decision, they have lost their potential power of developing into other kinds of tissue by taking the definite step which has converted them into the one kind. Irrevocable under normal conditions, but not, as we have seen, under abnormal conditions. Remove the influence of the surrounding connective tissue and the highly specialized tissue reverts again to the embryonic condition.

There is another side to the matter. The reverted tissue begins to increase; the cells of the kidney have lost this power, for the kidney when once fully formed in the adult maintains itself but does not increase in size. One of the most important properties of embryonic cells is their power of frequent division and so rapid increase. The reverted

kidney cells regain this power and quickly multiply.

So we see that, not only is the formation of any particular tissue conditioned by its surrounding tissues, but that the latter also prevent it from growing indefinitely and destroying the true balance of tissues and organs in the body. For the body is to be considered functionally as a socialist state, each constituent of which plays his particular rôle, but is dependent upon his fellows for his power to do so, and is checked by them when in danger of overplaying that rôle and so endangering the stability of the state; or structurally as a Gothic cathedral whose towering grace is the product of a delicate equipoise of forces, remove but one of those flying buttresses and the whole edifice comes crashing to the ground. Yet the body is more than the sum of many harmoniously running parts, for it is, as a whole, a living unity, and neither the most ideal of states nor the most perfect of cathedrals can ever be that.

And now let us finally consider what happens when, instead of running smoothly in concert, one or more of the tissues, overcoming the restraining influence of the surrounding tissues, increase to an abnormal

extent and destroy that all-important balance of forces. The many abnormal types of growth classified by pathologists as carcinoma, sarcoma, adenoma and the like, are all examples of tissues which have thrown off this restraining influence and developed at the expense of their surroundings. The study of tissue culture has taught us a great deal about such growths, which by becoming malignant, may develop into cancer. There are two conditions in which growths may be, benign or malignant. In the former the cells are still specialized and do not grow quickly or have any very harmful effect other than, in some cases, the application of pressure against a delicate structure, but the latter are formed of cells which have lost their specialized form, become embryonic and so able to multiply at great speed and, by renewing their youth in this unnatural manner, to feed upon the other tissues.

When malignant tissue is cultured artificially it goes on dividing and growing without any alteration, and when benign growths are cultured they gradually lose their specialized nature, become embryonic and so malignant. It has only been the restraining influence of the other tissues in the body, apparently,

which has hitherto prevented them from becoming malignant. So much, at least, have we learnt from tissue culture as to the nature of cancer and, it may well be, that with the increase of this branch of science we shall learn much more. Yet, considering how the health of each one of us is so delicately poised on a pinnacle composed of mutually dependent, and yet potentially antagonistic, struts, it is amazing not how often, but how seldom, it fails us.

18. *Regeneration in Animals*

Among the most interesting properties of living matter is the power it possesses of regeneration. All animals, in greater or less degree, are capable of reforming lost parts, the more lowly and simply organized animals having far greater powers in this direction than the more highly developed ones. Thus the protozoa, microscopic animals consisting of a single "cell" of which the amœba is the best known example, are capable of regenerating a complete animal from any piece, no matter how small, so long as the all-important "nucleus"—a minute body which occupies the centre of the

animal's body and appears to direct its vital activities—is present in that piece. In man, at the other end of the scale, only the skin can be regenerated; if a part is lost, new skin will grow over the wound, but the lost part will not be regenerated.

Description is always the first stage in any branch of science, and the study of regeneration began by a description of the many examples of regeneration which were found to occur naturally among animals. Later, in the hope of finding some explanation for these, animals were experimented upon and the results of cuts and grafts in various parts of the body were studied, while, as a final outcome, very largely of the study of regeneration has appeared the young science of tissue culture, which may be said to consist in the propagation under laboratory conditions of tissues taken from a living body in blood plasma, lymph or some artificially-prepared medium. By this means the growth of the tissues under various conditions can be watched under the microscope, and the influence of the different tissues upon the development of one another studied. Already most valuable results have been obtained from these investigations, while the prospects

which they have opened up for future work appear almost endless.

There are two types of regeneration. One is the perfectly normal process which takes place when there is a periodic loss of parts of the body. For example, many mammals and birds moult at various seasons of the year, but the hair and feathers respectively invariably grow again, and the same is true of nails. In a similar way snakes shed their skins, a new one having formed beneath; man, like all other mammals, at a certain age loses his first, or milk, teeth, which are replaced by the permanent set, while fish and reptiles are continually losing and replacing their teeth throughout life. Deer shed their antlers at the end of every year, but grow them again larger than ever the following year; insects regularly moult for the first portion of their lives, while such creatures as crabs, lobsters and shrimps continue to moult at regular periods during the whole of their lives. This type of regeneration is really a process of repair, and once this power is lost death must inevitably ensue.

The second type of regeneration, "restorative" regeneration, as it is sometimes called

only takes place under abnormal conditions, usually as the result of an accident. There are innumerable examples. In man, as we have seen, the skin can be regenerated while broken bones can be soldered together with new material; in birds the power of regeneration is also very limited, but storks and fighting cocks are able to grow new beaks if they should chance to lose this part, torn off, possibly, in the case of the latter, in a combat with a rival. Lizards, when attacked, will very often break off their tails near the base, but a new one always grows out from the stump of the old one. Newts and salamanders have an even greater power of regeneration; besides being able to grow new tails, many of them can re-form entire limbs, every bone and every muscle, after they have been severed at the base, while if the lens of the eye is destroyed or merely displaced, a new one is regenerated from the edge of the iris. Snails can form new tentacles or "horns" and other parts of the body; crabs, lobsters, and all animals like them can regenerate any of their limbs, and very often do so.

Earthworms, as is generally known, have an exceptional power of regeneration; if

cut in two the hind portion will develop a new head, and the fore part a new tail. There is a difference, however, in the behaviour of the two parts, whereas the fore part can grow a tail as long as the one it lost, no matter how much of the front end of the worm has been cut off, only a limited head end—five segments or " rings " at the most—can be regenerated from the hind part. There are certain small worms, known as flatworms, more simply organized than the earthworms, which possess practically unlimited powers of regeneration, only the very smallest fragment being unable to give rise to a new and complete animal. If one of these worms is cut in two transversely, the two pieces each give rise to a short thick worm which later lengthens out, by a process of redistribution of the substance of the body, until it attains the same shape as the full-grown worm, when it proceeds to grow to the size of a normal worm. When a similar worm is cut lengthways and the halves allowed to regenerate, new material is gradually added to the cut surfaces until the normal shape is reached.

Star-fish are frequently to be found on the seashore with one or more of their arms

in the state of being regenerated, while occasionally a "comet-form" may be seen in which one arm and the central disc are of normal size, the remaining arms consisting of rudiments which are regenerating from this fragment of the original animal. An unusual case is that of the sea cucumbers —animals related to the star-fish, but possessing the appearance which the name suggests— which on being handled or disturbed in any way, with the greatest readiness cast up their entire viscera, and then proceed at their leisure to grow a new set! All jelly-fish, sea-anemones and zoophytes have extensive powers of regeneration, while some sponges can be broken up and strained through fine meshed silk and yet the isolated fragments will congregate together and give rise to new individuals. In the protozoa, as we have seen, the power of regeneration is only limited by the necessity for the presence of a nucleus in the fragment.

Although in the majority of animals the loss which precedes regeneration is entirely beyond control, some animals have the habit of *deliberately* parting with a limb or other part of the body when they are attacked —on the principle, expressing it somewhat

unscientifically, that it is better to lose the part than the whole. This power is known as "autotomy". Near the base of the walking legs of the lobster there is a deep furrow, which is known as the "breaking plane" of the leg, and both in this animal and in its allies, the crabs, prawns and cray-fish, in which the same condition is found, the legs which are readily parted with if injured or caught in any way, invariably break off at this plane; the actual breaking being caused by a sudden contraction of the muscles at this point. The wound, owing to the depth of the furrow, is small, there is little bleeding, and the exposed surface is quickly covered over with new skin. Next time the animal moults, the rudiments of the new limb push out quickly before the new shell has had time to harden, and there is a similar increase at every moult until the regenerated limb has attained the size of the others. Star-fish have a similar habit; some, appropriately known as brittle-stars, have only to be picked up, no matter how gently, and they immediately shed the greater part, and often all, of their limbs, which they will then proceed to regenerate if left alone. It is a common experience among people

who have attempted to catch lizards to be left firmly grasping the reptile's tail while its late owner darts away into safety. There are many other examples of autotomy, and there can be no doubt that the possession of this power enables its owner to escape what would otherwise be certain death.

Some very interesting cases of regeneration have been induced by experimenting with animals in various ways. There is a minute creature called Hydra which lives in fresh water and has a thin body not more than a third of an inch long, bearing a mouth surrounded by a ring of tentacles at one end, which, if split lengthways and then split again and again as it regenerates, can finally be made to carry as many as seven heads, like the mythical monster it is named after. The same kind of result is obtained when flatworms are treated in this manner. Interesting results are obtained by splitting one of these animals backwards from the head and then keeping the cut pieces apart. If the cut does not extend very far two heads are formed, one from each of the halves of the original one, but if the cut is made longer, two mouths are also formed (the mouth in these worms is situated in the middle of the

underside of the body) so that, finally, practically two complete animals are produced, only united by their tails. Similar results are obtained when they are split from the tail forwards, two entire animals being formed, which are joined together by the extreme tip of the head. Lizards have frequently been found in nature with two or more tails, and this condition can be brought about experimentally by cutting the tail obliquely. Instead of regenerating a single tail, as would have happened had the cut been transverse, two tails or even three are formed. Tails are not the only parts which can be duplicated, for example the leg of a newt may have a second smaller one attached to it, the result of a wound made in the top of the leg.

Instead of the part which has been lost being regenerated, it sometimes happens that something quite different is formed. These apparent mistakes on the part of certain animals are known as cases of "heteromorphosis", and it is very difficult to find any explanation for them. The eyes of prawns and crabs are borne on the ends of short stalks, and if the stalk is cut just below the eye a new eye will be regenerated, but if

the stalk be cut well below the base, instead of an eye a long feeler, of which the animal already possesses two pairs, grows out from the cut surface. There is a delicate little zoophyte known as Tubularia which consists of a branching colony bearing tiny heads each with a mouth and two rings of tentacles, at the end of short stalks. If a stalk is cut a short distance below the head, a new stalk will regenerate from the cut surface, and a new individual, and finally, a new colony, will be formed. If, on the other hand, the cut is made immediately below the outer row of tentacles, a second mouth surrounded by a single ring of tentacles will be produced, the resulting organism consisting of three rings of tentacles and two mouths, but with no body to which they can pass the food they capture. In much the same way the head of a flatworm will regenerate a second head if cut immediately behind the eyes, while by suitable treatment a worm can be produced with a complete body and a head at either end.

Of essentially the same nature as regeneration is the power which enables us to graft together pieces of different individuals of the same, and in a few cases of different,

species. The hind half of one earth-worm can be grafted on to the front half of another and the two parts will unite perfectly to form a single, apparently normal, individual. Even when two tails are grafted together they will unite to form a headless worm, which, though unable to feed, may live for several months; or an additional tail may be grafted on to the side of a complete worm and a two-tailed worm produced. It is possible to graft pieces of the simple little Hydra to one another in the most complicated manner, animals being formed which may be made up of five pieces of Hydra which have united and then regenerated four heads, some of which may be formed by the union of two pieces. The hind half of one frog tadpole can be successfully grafted on to the front half of another, even occasionally when the two halves belong to different kinds of frogs, and the resulting organism has been kept alive until after it changed into a frog, each part still retaining the characteristic features of the particular type of frog to which it originally belonged. In man the power of grafting, like that of regeneration, is very limited, and it is only possible to graft pieces of skin or bone, though this

has of late years been carried to a fine art, particularly when dealing with men mutilated in the war.

The earlier the stage of development, the greater appears to be the power of regeneration. Any piece of a fertilized egg of a sea-urchin, provided it contains a nucleus, will give rise to whole small embryo and, finally, to a normal adult. In the normal course of events the developing egg first divides into two parts or "cells", then into four, eight, sixteen, thirty-two and so on, although this orderly sequence gets lost in some animals much sooner than others, as development proceeds. If the developing eggs are shaken or treated in any other way so that the individual cells come apart, it has been discovered that in the case of a large number of animals any *one* cell from any stage up to the sixteen-cell stage is capable by itself of forming a complete, though small, embryo. What are known as "like" twins are produced by the separation and subsequent independence and development of the first two cells into which the human egg divides as it commences to develop. In the lower animals small pieces taken from more advanced stages in develop-

ment are often capable of regenerating a complete embryo.

When it is asked, What is the cause of this wide-spread power of regeneration? the answer is difficult. It has been conveniently explained by some zoologists as a particular power which, on account of its great use to its owners, has been "selected" by the action of natural selection. They argue in support of this view that it is best developed in those animals to which it is the greatest use, but their arguments will not stand very critical examination. Regeneration is akin to growth itself—indeed, in some animals which reproduce themselves by budding or by dividing in one manner or another, it is difficult to say whether the process is one of regeneration or growth or a combination of the two—and so an inherent property of living matter, not some chance variation which has been selected because it proved useful. The reason why the power of regeneration is so much greater in the lower animals is that their cells are less specialized than those of the higher animals. In the normal course of development an organism at first consists of a number of cells all alike and all equally capable, apparently, of giving

rise to any of the tissues of the adult; but later certain cells get specialized, some form muscles, some nerves, some the digestive system, and so on, and as a result have no longer unlimited potentialities. It is the same in regeneration, there must be a number of unspecialized cells which are capable of developing into those parts that need to be regenerated, or else the cells must be so slightly specialized that they can easily revert to the simpler condition and then become specialized for the new requirements. This state of affairs is only present to any large extent in the lower animals. Loss of the power of regeneration is one of the prices we have to pay for the progress of evolution and for that ever-increasing specialization which has resulted in the production of the human race.

19. *On Growing Smaller*

Growth is naturally associated in our minds with an increase in size; we think, inevitably, of the child which grows up to become a man, of the chick which loses its round fluffiness as it develops into a long-legged pullet and finally into a fully grown

hen, or of the tiny seed which quickly germinates in the soil and sends up a shoot which is soon transformed into a large plant. And this association is entirely justified, for growth—under natural conditions—*does* imply an increase in size, and, at the same time, an increase in complexity. Going back a stage before the chick to the egg from which it hatches, the embryo begins as a thin streak upon the surface of the yolk, and this develops, not only in size but also in complexity, as time passes, for gradually the various organs of the body, eyes, brain, lungs, stomach, kidneys, to name but a few, are formed, so that when the chick emerges from the egg it is a perfect animal, with all its organs fully formed, and only needs to increase in size to become an adult hen.

But paradoxical though it may sound, certain animals can, as the result of adverse or abnormal conditions, actually grow smaller. This, of course, does not apply to the more highly organized animals, such as the vertebrates, which include the fish, amphibians, reptiles, birds and mammals, in which the presence of a firm skeleton and of a very delicate equipoise of organs and tissues make any reduction in size impossible. If

insufficiently fed, they may grow slowly and fail to attain the usual size, but they cannot, under any circumstances, become smaller. Many, however, of the more simply organized animals are not so hedged about by the rigid requirements of the laws of physics.

In some of these creatures a decrease in size is a perfectly normal affair in their lives. Let us take the case of certain of the sea-squirts, common seashore animals which live attached to rocks, and which, on account of the appearance of a "tadpole" stage in their early life history, are supposed to be degenerate relatives of the lordly vertebrates. Some of these animals form large colonies in the summer months, but on the approach of the cold winter weather these die down to little whitish masses. A close examination shows that each individual or "zooid" has completely lost its normal organization, and that a small white mass containing several cavities is all that is left of the former animal, which possessed well-developed digestive, nervous, excretory, respiratory, circulatory, and reproductive systems. Thus not only has the creature grown smaller, but it has lost its complex organization—it has reversed the normal process of growth in both

of its essential characteristics. Exactly the same thing happens if healthy, fully developed animals are placed in impure water; they grow backwards until they become little whitish masses.

It might be thought that this process was one of decay, that the creatures were dying slowly. But this is far from being the case, for when the spring comes the animals which have grown smaller in the winter increase in size and regain their former organs, while the animals which had grown smaller in the impure water become large and complex once more when replaced in pure water. And so these animals can grow larger and then smaller, become highly organized and then revert to a simple embryonic condition; and, when conditions are altered, they can reverse the process.

Other animals which can grow smaller under adverse conditions are to be found amongst the members of that group which includes the sea anemones and the jelly-fish. By starving a jelly-fish one can make it grow smaller and smaller and change its shape so that from a flat, saucer-shaped animal it becomes a small, spherical mass. In the same way a sea anemone becomes

gradually smaller though without altering its shape, but when it is fed again it quickly starts to grow larger and soon attains its former size. The little flatworms react in the same manner to starvation, decreasing in size but retaining the same bodily proportions and all the organs of the body.

The living matter or "protoplasm" of which animals are composed regulates in some manner of which we have, as yet, no knowledge, the form of the adult animal. Although the eggs of many animals may all appear very similar in structure, size, and chemical composition yet there is some characteristic substance present in the eggs of each species which determines that that egg shall develop in a certain manner and into a particular animal. Growth in size and increased complexity in structure both take place as the egg develops first into an embryo and then into the fully formed animal, but, under normal conditions, they follow a perfectly definite course, one process following another in an orderly sequence of events. But place these animals under abnormal conditions and, if they are sufficiently simple in organization and so plastic, they may, as we have seen, reverse the normal

sequence of events. But though they decrease in size they may retain, as in the case of the sea anemone and the flatworm, the same relative proportions of the body. In other words, the regulative mechanism which controls the development of the different organs and tissues in the body still retains its influence. This fact provides us with striking evidence of the delicate balance of forces of which the harmonious functioning of any individual organism is the summation. Should the regulative mechanism fail to exert its proper effect, then one particular tissue may get out of hand and grow at the expense of others, which is what happens in cancer.

Where the animals not only decrease in size, but also lose their adult organs, it does not mean that this regulative mechanism has ceased to act, but that the process has gone one stage further back. The animal has reverted not merely to the size of a smaller individual, but has actually gone back to the earliest, or embryonic, condition. The first cells which are formed when the egg begins to develop are entirely unspecialized, each is capable of doing the same work, it is only as the organism gradually becomes more complex, as the various organs and

tissues of the adult body begin to be formed, that the countless minute cells of which the body is now composed lose their embryonic character and become specialized in various ways, some as muscle cells, others as nerve cells, others again as components of the digestive or reproductive systems, and so on. The sea squirt of which we wrote loses its adult structure and reverts to a mass of unspecialized, embryonic cells which, like the cells of the early embryo, are potentially capable of doing the work of any of the tissues and of developing, when the adult body is reformed, into any part of it. The scientific term for the increased specialization of the cells into different tissues as the body develops from the embryo is "differentiation", and so for the opposite process, the change from the specialized to the embryonic condition, the cumbersome, but self-explanatory, word "dedifferentiation" has been increasingly used.

Death is the inevitable result of specialization. The only animals which can truly renew their youth are those which are capable of reverting to the unspecialized, embryonic condition. The simplest of all animals, the protozoa or single celled animals, appear

always capable of doing this; they multiply by a process of division and are potentially immortal. The sea squirt which can revert to the embryonic state may also be said to be capable of indefinite renewal of life and activity. The more highly organized animals pass from the embryonic state into one of the highest specialization from which there is no return.

IV. Biology in the Field

20. *The New Natural History*

Until the middle of the nineteenth century, zoologists were concerned above all things with natural history. The great majority of them were country gentlemen with sufficient means, ample leisure and a passion for animals; they spent their lives observing the habits of animals, often with an infinity of care, and, in the case of the more adventurous who wandered into strange new lands, in the often rather superficial description of new members of the fauna. A few only, and they were mainly confined to the museums and

universities, occupied their time with the structure of animals and still fewer had the comprehensive knowledge necessary for drawing up great schemes of classification, such as the one we associate with the name of Cuvier.

So long as the doctrine of special creation was held, the study of animal structure could not be one of the first importance, because the facts so acquired would be completely isolated and incapable of throwing light the one upon the other and initiating the analysis which, following upon description, is the second step in all scientific enquiries. Darwin was one of the greatest of field naturalists, and he was also a great scientific zoologist; he may be considered, in the first part of his career, as the last of the old naturalists, and in the latter part as the first of the new zoologists. By demonstrating with incomparable skill the essential unity of the animal kingdom, Darwin showed the importance of the comparative study of the structure of animals and of the utmost exactness in the description of species; he had elevated zoology to the standing of a science and accurate description of the subject matter was clearly the first thing needed.

And so natural history was abandoned by many of its former devotees who, together with the many vigorous new workers who had been attracted to zoology by that glimpse of the wider horizon so temptingly given by Darwin, turned to the laboratory and the museum, to the microtome and the microscope, with an industry to which a series of great monographs on the development, structure and classification of almost all groups of animals, bears most eloquent testimony. The mass of evidence in favour of evolution was greatly increased, while the basis of description for the new science of zoology was well and truly constructed.

For practically two generations zoologists were almost exclusively thus employed, and when at last it began to be realized that the base of their science was strong enough to support superstructures, the younger zoologists had neither the training nor the inclination to return to the field observations which had occupied their great grandfathers. Instead they took up the study of genetics and cytology (the science of the cell) or the investigation of the functions of the various organs in the simpler animals. They either ignored or failed to realize that the

increase in knowledge, not only in zoology but in all the other sciences, made possible field work of a scope and of a value far transcending that of the old naturalists.

The United States of America have led the way in the return to natural history, more perhaps through necessity than choice, since the American Bureau of Biological Survey, which is responsible for much of this work, was originally founded that it might investigate the problems which the establishment of the English sparrow in that country had caused. We have lagged sadly behind in similar work in this country—one reason for which is doubtless the lack of urgent economic necessity—and the publication of an extremely interesting book by Mr Charles Elton on *Animal Ecology*,[1] which is the scientific name for this new natural history, is both gratifying in its evidence that first-class work on this subject is being carried out in England, and also illuminating in its exposition of the value, in some cases urgent necessity, of the work there is to be done.

The section of Mr Elton's work which deals with the numbers of animals and their varia-

[1] *Animal Ecology*. By Charles Elton. Sidgwick and Jackson. 10s. 6d.

tions is of extraordinary interest, both intrinsically and in view of the influence these variations may have on man directly, on his handiwork, or his domestic animals and crops. For we must remember that, in spite of our great and increasing knowledge and mastery over natural forces, we are all of us members of the animal kingdom and, though our influence on our lowlier and less intelligent relatives is often devastating to the extent of the obliteration of an entire race—the Dodo is but one example—they are not without their influence on us, and have their revenge in a thousand ways, some blatantly open, others stealthily insidious.

While it is, of course, well known that the potential powers of increase of any animal are far in excess of the actual rate of increase —the implications of which were first realized by Darwin, who showed that natural selection weeds out all save the most fitted of the progeny—yet it will probably come as a surprise to many to find that on occasion natural selection may cease to act, and so the potential will become the actual rate of increase. Thus in Central Europe there are regular plagues of cockchafers at definite intervals, the insects doing immense damage

to crops and forest trees. These plagues occur every three years in some places, every four years in others, but in all cases with perfect regularity—in some instances records go back for sixty years. The remarkable periodic increases in the lemmings of Norway, which migrate in vast numbers until they reach the sea into which they plunge without hesitation, all eventually to be drowned, have excited astonishment for centuries. These "lemming years" have occurred recently every four years, but in the last century they were more frequent, every two or three years, while Mr Elton establishes the remarkable fact that the Canadian lemming has periodic increases which coincide almost exactly with those of the Norwegian lemming. Obviously a common factor is at work, which he thinks can only be climate.

Other rodents have years of great abundance, when the rate of increase is apparently almost completely unchecked, to be followed by periods when it is difficult to find a single animal, in much the same manner as the lemming. In two ways is man affected. When they are abundant the animals may do immense damage to crops, while, on

the other hand, they may in those years provide food for animals of economic importance. An example of the latter is provided by the Canadian lemming, which is preyed upon by the valuable fur-bearing Arctic fox, which is always trapped in greatest numbers during good " lemming years ".

A period of abnormal increase is not unfrequently the fate of an animal which invades a new country or new environment. After a few years, during which they are establishing themselves and are hardly observed, the animals often appear in countless numbers. The well-known story of the introduction of rabbits into Australia immediately comes to mind, but, as Mr Elton shows us, this is but one example out of many; both starlings in New Zealand and the Gipsy Moth in America spread in a similar destructive plague over the country. In the latter case the value of this new natural history was well displayed, for investigation showed that the reason for the increase was the absence of the parasites which controlled the numbers of the moths in Europe; these were promptly introduced, and the numbers were brought down. We may add a further example not mentioned.

In 1914 the common Shipworm of Europe was observed boring into timber in San Francisco Bay, whither it had probably been carried in the hulls of wooden ships. Beginning in 1917 the wood-borers began to extend their activities with alarming results. Wharves and wooden docks began first to crumble and finally to collapse entirely so that by 1921 damage to the extent of over fifteen million dollars was reported. In this case not only was the Shipworm displaying the accustomed vigour of a newcomer, but it was greatly aided by the small amount of fresh water brought down by the rivers in those years, which enabled it to pass further into the Bay than would normally have been the case, for the Shipworm cannot live where much fresh water comes into the sea.

The majority of well-established animals have a definite " optimum density ", which if they exceed the excess are promptly killed by their enemies—the enemies of the individual but the true friends of the race—while if the numbers fall below it their enemies fail to hunt with the necessary added vigour, and so the accustomed density of population is quickly regained. The various constituents of the different animal communities

are maintained in a state of balance, the controlling factors in which it is the function of the ecologist to discover; on the occasions when that balance is apparently lost, as in the cases we have quoted, he has a still more obvious (though not necessarily easier) task before him. Like all true sciences, the new natural history must be largely quantitative: there must be counting and measurement, and estimations of the relative influence of different factors. It is capable of adding greatly to knowledge and of furnishing the greatest assistance in the economic development of the world.

21. *Life Within Life*

Complex though the study of plants and animals may be, yet one thing is clear; nothing lives unto itself, life is a great organic unity whose multitudinous members are entirely dependent the one on the other. In some cases this interdependence is not apparent on the surface although a more careful examination will always reveal it, in others there are definite associations, two entirely different creatures being dependent on one another for food, shelter or reproduction

while finally there is a still more intimate partnership in which the members live in the closest possible relationship—one form of life actually within another. This, of course, may take the form of parasitism, in which case the advantage is entirely on the side of the parasite, but it may also be to the mutual advantage of the organisms concerned, and it then receives the name of "symbiosis" from Greek words meaning to live together. So intimate may be this type of partnership and so great the mutual need of the members that they are unable to exist apart. The unravelling of these intertwined threads of life has provided one of the most fascinating chapters in the book of biology as an account of two of the most interesting examples will perhaps indicate.

The termites or "white ants" are a group of insects which live in organized communities, like the true ants or the bees, with various types of individuals or "castes"—workers, soldiers, etc. The majority of them live on wood and do so much damage to buildings in the tropics as to constitute a serious pest. It is invariably the case that when these termites are opened their stomachs are found packed with minute unicellular animals or

protozoa. Their presence was for a long time a mystery, but by a series of very ingenious experiments it has recently been discovered by an American scientist that it is possible to kill all the protozoa without damaging the termites in which they live, and that, as a result, the termites are no longer able to extract nourishment from wood; they eat it as hungrily as before, but they are unable to live on it, and in a few weeks all are dead.

He then proceeded to examine the protozoa, and found extremely minute fragments of wood within them, some of which were apparently being digested. Since he also knew that the protozoa could live indefinitely in termites fed exclusively on wood, but died when the termites were given other food, he came to the inevitable conclusion that it was the protozoa and *not* the termites which digested the wood.

It is clear from these experiments that we have here to do with a perfect example of symbiosis between two very different types of animals. The protozoa cannot exist apart from the termites, and only within them when the latter are feeding on wood, while at the same time the termites cannot

live on the wood without the help of the protozoa, which digest it for them. So both parties gain by the arrangement; the protozoa are sheltered and provided with their especial food by the termites which, in their turn, are enabled to live on wood which they cannot digest for themselves but which the protozoa digest for them.

To turn to a very different animal and a still more interesting case of symbiosis. There lives on the sandy shores of northern Brittany and the Channel Islands a little flatworm, only one-eighth of an inch long and bright green in colour—like the tiny fragment of a leaf. It occurs in large colonies, which forms green patches on the yellow sand, and is an animal of the most regular habits, suddenly appearing from beneath the sand immediately after the tide has left it, and disappearing just before the sea returns. This little creature is known as Convoluta, and its peculiar structure and mode of life have been very carefully studied. It has been found that the green colour is due to the presence in the tissues of a vast number of minute plant cells which are not present in the egg, but with which the animals become infected in the early stages of development;

if they are kept free from infection by artificial means they cannot develop properly and soon die.

Like all other plants the green cells are able to form starch out of water and carbon dioxide with the aid of sun-light, and a great deal of the starch is handed over to the animal. Although it is able to feed in the usual way in early life, Convoluta soon finds that it is much simpler to depend entirely on the starch from the green cells, and as a result of disuse its digestive organs degenerate so that it can no longer, even if it so wishes, feed like a normal animal. This is the explanation of its regular habits, for, in order to obtain the sunshine without which the green cells cannot do their work, it has to expose itself to the full glare of the sun for as long as possible.

In time, however, the green cells are unable to supply the growing needs of the animal, which begins to feed on them so that they gradually disappear, and at this stage a Convoluta presents the strange appearance of an animal with a green head and a white tail. Finally, having killed its best friends, the little flatworm pines away and dies, though not before it has laid great num-

bers of eggs which will maintain the race.

Here we have a case of union between animal and plant. It is perhaps hardly so perfect an example of symbiosis as the other because, though the plant receives both shelter and supplies of certain necessary foods from the worm, it is eventually destroyed: while the worm receives food from the green cells, but not enough, and so is forced to destroy the very organism on which its life depends. Moreover, though Convoluta is absolutely dependent on the green cells, they are quite capable of living freely in the sea. But for the greater part of their life together, Convoluta and its green cells represent one of the most remarkable cases of symbiosis of which we have knowledge.

22. *Rats and Man*

In spite of his ever-increasing knowledge and mastery over nature, man is still influenced profoundly by his surroundings, and especially by the other animals—though not, it is true, to the extent to which many of them are influenced by man. The larger and more obvious enemies of man, such as the man-eating carnivores of the tropical regions,

have long since been decimated by modern fire-arms and more primitive traps, but the many smaller, more insidious and infinitely more dangerous of his foes still remain largely unconquered, and constitute one of the greatest problems of modern science.

Rats rank very high in the list of these enemies of mankind. Not only do they do enormous damage to food supplies, a fact which is widely known, but they are the carriers of one of the most terrible of diseases, bubonic plague. This is a bacterial disease, the bacillus being very common in the rat which, through long experience of it, has ceased to be very seriously affected by it. Rats are one of the happiest hunting grounds of fleas which, as too many of us know by bitter personal experience, live by biting through the skin of the animal they live on, and then sucking its blood. Now the bacteria in the blood of a plague-infected rat affected the flea by multiplying in its stomach until it is choked, so that when next it tries to feed, it is unable to suck in blood, but reguritates some of the bacteria in its vain efforts to do so. This is the way in which other rats, and also men, are infected by plague.

In the Middle Ages and until the end of the seventeenth century Europe was constantly devastated by bubonic plague, and then suddenly, apart from small, local outbreaks, the awful scourge disappeared except in the eastern portions of the continent. The medical profession had nothing whatever to do with this, it remained completely ignorant of the cause of plague for another two centuries, and the whole business, the cause of which is now clear enough, can only be regarded as one of the most amazing pieces of luck ever experienced by suffering humanity.

The rats which swarmed in Europe at the time of the Black Death, when it is estimated that some twenty-five million people died, and in London at the time of the Great Plague of 1665 when at least one hundred thousand people died, were all Black or Ship Rats. These animals live and breed in houses and always, as far as possible, in close contact with man. Providing as they did an inexhaustible reservoir of the bacillus, it is no wonder that Europe was never free from infection. These rats originally came from the East, the original home of plague, and are still the most common species in India.

It happens every now and again, we have little idea of the cause or causes, that some animal suddenly increases to an almost unbelievable extent, and because they are unable to find sufficient food in the ancestral hunting grounds many of the newcomers migrate in the hope of finding new feeding grounds. Some such abnormal increase happened to the Brown Rats—mistakenly called the Norwegian Rat—in their ancestral home in Asia about the beginning of the eighteenth century. Like Atilla and the Huns of old, they swept in their millions into Europe, and in 1727 countless numbers were seen swimming the Volga and pouring into Russia. Quickly they spread over the whole of Europe, entering this country by way of ships. The Black Rats were unable to resist the onset of the newcomers, which were both larger and fiercer than themselves, and it was not long before they were almost completely wiped out. At the present time the Black Rat is a rare beast in this country, though it still survives in ships.

The conquering Brown Rat had very different habits from its victim and predecessor. It had none of that animal's preference for the society of man, on the

contrary it is extremely shy of him and avoids him as far as it can, so that in the country it established itself under hay ricks and in ditches, or in the towns in granaries, docks, slaughter-houses and sewers. For this was at the time of the early development of modern sanitary methods, and the newly built sewers were promptly occupied by the Brown Rats, which found their conditions ideally suiting them.

Greater cleanliness and improved sanitation undoubtedly played their part in the disappearance of plague—the destruction of so much of the filthiest parts of the town by the Great Fire was probably one of the chief reasons why London was never again afflicted with plague to any great extent—but the greatest cause of all, undoubtedly, was the change in the rat population. At the time of the Great Plague of London, the Black Rats were everywhere abundant in the houses, and no one seemed to worry much about them. Both dogs and cats were suspected as being the carriers of Plague and were ruthlessly destroyed by order of the City council, but rats were entirely overlooked. The extinction of these rats and their replacement by another kind which, though

it can possess plague bacillus and be infested with fleas like its predecessors, avoids man to an even greater extent than the other sought him out, is the most important cause of the disappearance of plague from Europe. The last outbreak of any magnitude occurred in Southern France in 1720-22.

It was not until 1894 that the first clue in the chain of evidence which was to prove the rat responsible for the carrying of plague was found, when a Japanese doctor named Kitasato discovered the plague bacillus during an outbreak at Hong Kong. Gradually the responsibility first of the flea and then of the rat was shown. But it would have gone hard with Europe if she had had to wait till the beginning of this century before overcoming plague, and never has man had more reason to thank these strange forces of nature which make and unmake Empires in the animal world, nor been furnished with a more striking example of the closeness of his association with the other inhabitants of the earth, than as a result of the invasion and conquest of Europe by the Brown Rat.

V. Tailpiece and Moral

23. *Bathybius*

By its demonstration of the common origin and so essential unity of the multitudinous forms of life, the final establishment of the fact of evolution by Darwin raised zoology to the status of a science. What had previously appeared a chaos of warring, dissimilar elements, became, at the waving of the wand of genius, clearly seen as an ordered assemblage, all its members descended from a common ancestor, at the same time mutually antagonistic and wholly interdependent ; the whole a balanced unity. The study of zoology immediately acquired a new standing in the eyes of inquiring men, and throughout the domain of Western civilization hundreds of eager minds sought to verify the work of the master, to extend it and to probe into the very roots of the great tree of life, on whose massive boughs and countless fine branches, ever growing, are borne the myriad forms of life, from protozoans, lowly alike in structure and mental powers, to animals

of the vastness of whales and of the intellect of man.

The pendulum had swung to the other extreme. Where all had been hesitation and doubt was now boldness and certainty. Only too often the followers of Darwin were characterized by a cocksureness and a dogmatism which were as greatly in excess of that of their master as their knowledge and patient pursuit of truth fell short of his. Amost daily some detail was added to the tree of evolution, some twig fastened to a branch, the junction of some great bough with the massive trunk discovered—not infrequently, in several places at once! Where gaps still remained a series of supports in the form of facile theories were introduced in place of the solid wood, theories which often postulated the existence of some linking animals whose creators, in moments of absentmindedness, frequently forgot to furnish with the organs or balanced structure necessary for life, and which at best would as often as not have been rejected by that sieve of natural selection of which their creators were the most vocal defenders.

But it was the origin of life which, as ever, exerted the greatest fascination and called

forth the most numerous and most elaborate theories. It was recognized that the apparently simplest of protozoans, the Amœba, was yet a comparatively highly organized creature, and some connecting link between it and lifeless matter was freely postulated and as confidently sought.

The discovery of this, and many other of the "missing links", was expected as an outcome of the investigation of the life on the bottom of the deep seas which was at that time beginning and was to be continued by a series of great expeditions organized by almost all the maritime nations of Europe. This hope was changed into something approaching certainty when examinations of mud taken from the bottom of the Atlantic and preserved in alcohol revealed the presence of a quantity of soft gelatinous matter. Professor Wyville Thomson, in his account of the work of the "Porcupine" and the "Lightning", two of the earliest of deep-sea expeditions, in 1868-70, speaking of this substance, says (*The Depths of the Sea*, page 411): "If the mud be shaken with weak spirit of wine, fine flakes separate like coagulated mucus; and if a little of the mud in which this viscid condition is

most marked be placed in a drop of sea-water under the microscope, we can usually see, after a time, an irregular net-work of matter resembling white of egg, distinguishable by its maintaining its outline and not mixing with the water. This network may be seen gradually altering in form, and entangling granules and foreign bodies change their relative positions. The gelatinous matter is therefore capable of a certain amount of movement, and there can be no doubt that it manifests the phenomena of a very simple form of life."

Already Professor Huxley had christened this simplest of all forms of life *Bathybius hæckelii*, and the observations of Wyville Thomson appeared to set the seal of certainty upon Huxley's deductions from his alcohol preserved specimens. Haeckel, the great protagonist of Darwinism in Germany, and the most ingenious creator of those hypothetical animals whose weird and mysterious forms run wild over the pages of zoological literature of that period, embraced this god-child with an enthusiasm surpassing that of its true parent. He immediately wrote a paper entitled "*Bathybius* und das freie Protoplasma der Meerestiefen", in which

he discussed the nature, origin, destiny, and place in the economy of marine life of this primitive form of life, concluding by asking, "Have we not here the case of protoplasm coming continuously into being by creation? We stand face to face with a series of dark enigmas, the answers to which we must hope to receive from future investigations."

And so it was that with the further investigation of *Bathybius* and with a possible solution of the greatest of all problems, the origin of life, as important parts of the programme, the "Challenger" set forth on her epoch-making oceanographical cruise in 1872.

The gelatinous matter was brought up from the great depths in quantity, but, in spite of the continuous observations of the naturalists attached to the expedition, no sign of the movements so vividly described by Wyville Thomson could be detected. Meanwhile the chemists on the *Challenger* were exercising themselves on the problem, and were puzzled at being able to detect no trace of organic matter when water supposed to contain *Bathybius* was evaporated to dryness. Finally, when they were cruising between China and Japan in the early part of

1875, it was discovered by Mr J. Y. Buchanan, the senior chemist, that *Bathybius* was in reality not an organic body but was, in his own words, "sulphate of lime, which had been eliminated from the sea-water, always present in the mud, as an amorphous precipitate on the addition of spirits of wine. The substance when analysed consisted of sulphuric acid and lime; and when dissolved in water and the solution allowed to evaporate, it crystallized in the well-known form of gypsum, the crystals being all alike, and there being no amorphous matter amongst them."

The sad news of the rather ignominious death of *Bathybius* was quickly known in England, and the Professor of Chemistry at Edinburgh University was able to demonstrate the manufacture of *Bathybius* in his laboratory. Huxley received the sad news of the demise of his protégé with dignity, admitted his mistake, and is said to have referred sadly to *Bathybius* as "not having fulfilled the promise of its youth". Haeckel's remarks are not recorded, but he was significantly silent for ever after on the subject.

The day has long passed now when we can hope for any such short cut to the dis-

covery of the origin of life as *Bathybius* during its short existence appeared to offer to our grandfathers. The further science progresses the more do we realize the immensity, the infinite complexity of the subject, and the solution of the problem recedes ever further and further into the remote distance until we may well doubt whether it ever can be solved, though to allow such a doubt to affect our outlook would be fatal, for to the scientist the laws governing all processes must be possible of investigation and final elucidation. Further science cannot go, to admit the possibility of less is to betray our calling.

And the moral of the sad story of *Bathybius* is just this, that a scientific theory if based on all available knowledge is often of the greatest value, and science has repeatedly been advanced by great strides as a result of these inspired guesses, but such a theory if based on insufficient evidence or persisted in despite the emergence of discordant facts is the greatest hindrance to the investigation of truth and the cause of the disrespect into which any science may fall. Would that all could be as promptly destroyed as was *Bathybius*.